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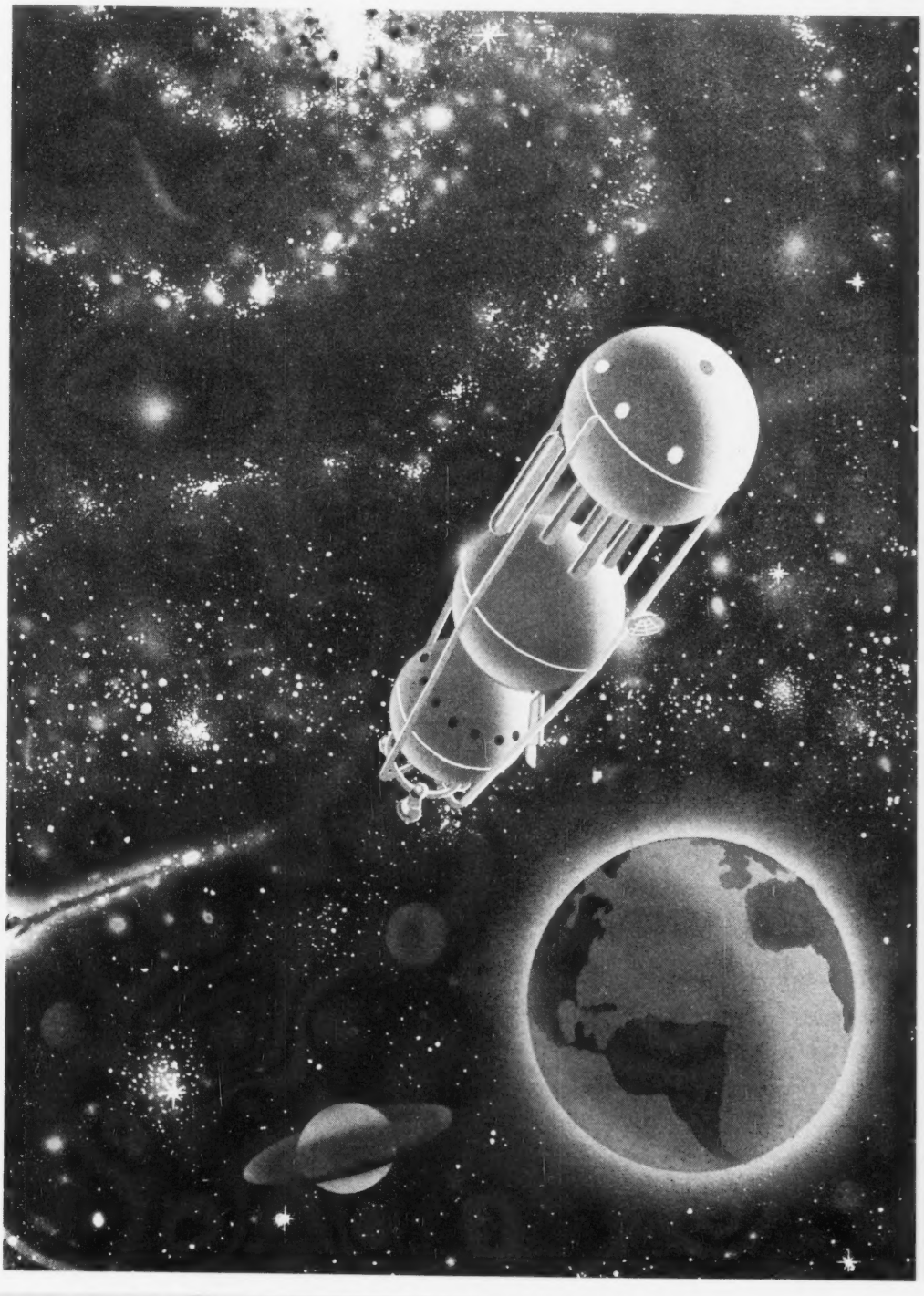

JUNE 1960

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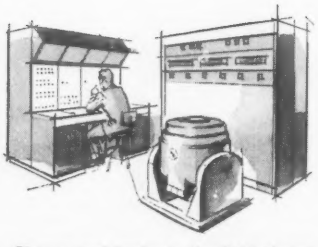

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For active Environmental Engineers and the executives throughout industry who are concerned with the advancement of Environmental Engineering by the Institute of Environmental Sciences.

Charles W. Danielson, Technical Editor

Robert Whiting, Associate Editor

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JUNE 1960

IN THIS ISSUE

6 A Synopsis of Natural Environments to Heights of 1000 Km

12 National Meeting and Equipment Exposition 1960

14 The President's Corner

14 Notes From The Editor

15 Development of a Combined Climatic, Static & Dynamic Environmental Test Facility

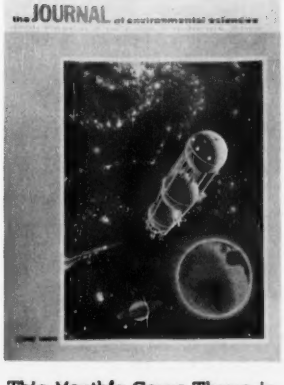
24 Biological Effects of High Intensity Noise

27 Technical Information

28 IES News Letter

28 Membership Information

30 New Products



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THE JOURNAL OF ENVIRONMENTAL SCIENCES is published bi-monthly at 11916 West Washington Blvd., Los Angeles 66, California. Subscription Rates: $5.00 per year (6 issues) in United States and Possessions and in Canada. $1.00 per copy when available.

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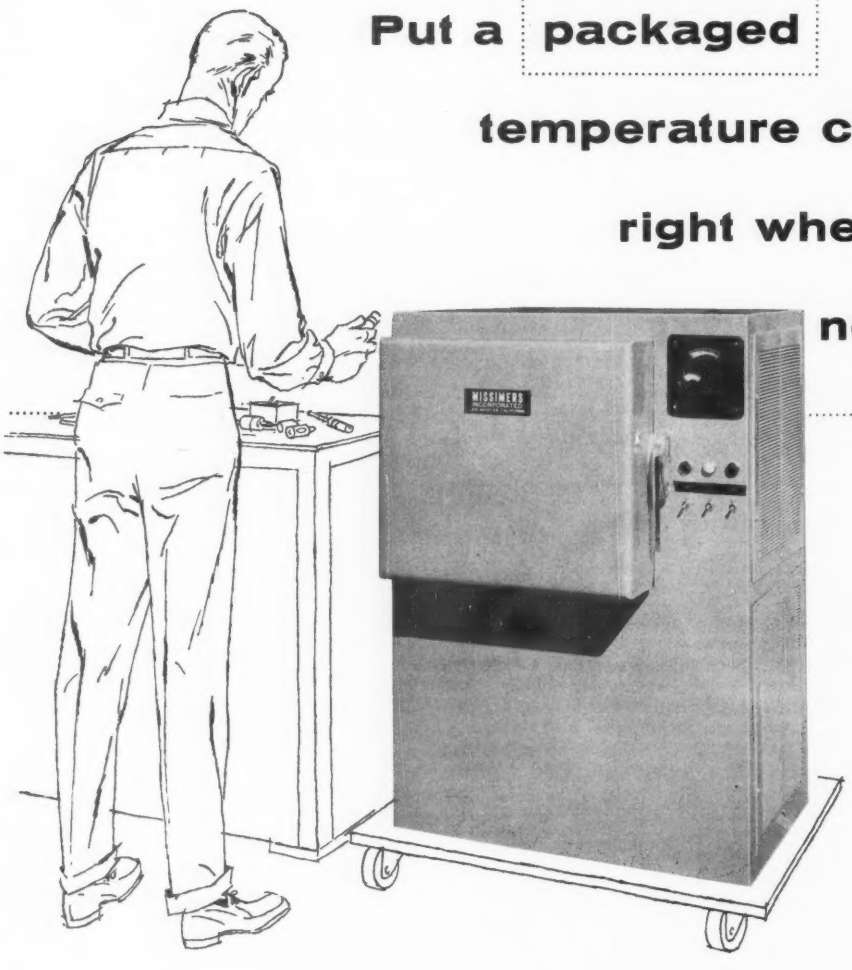

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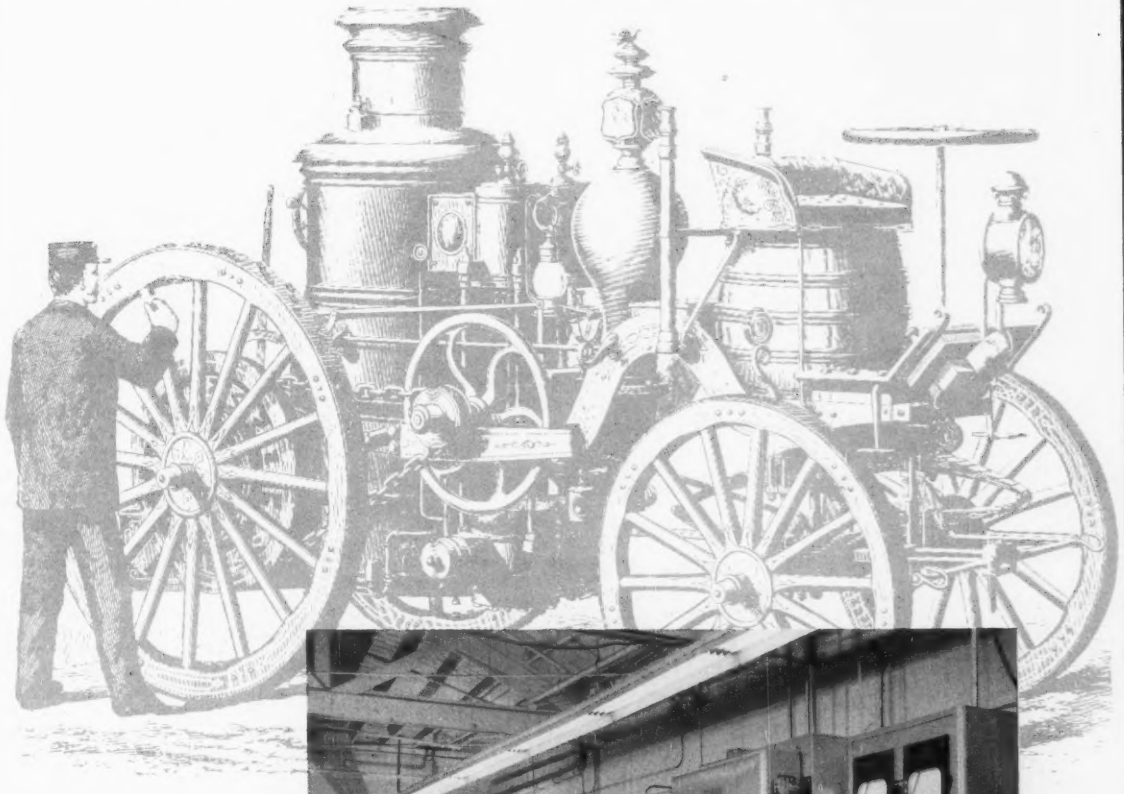

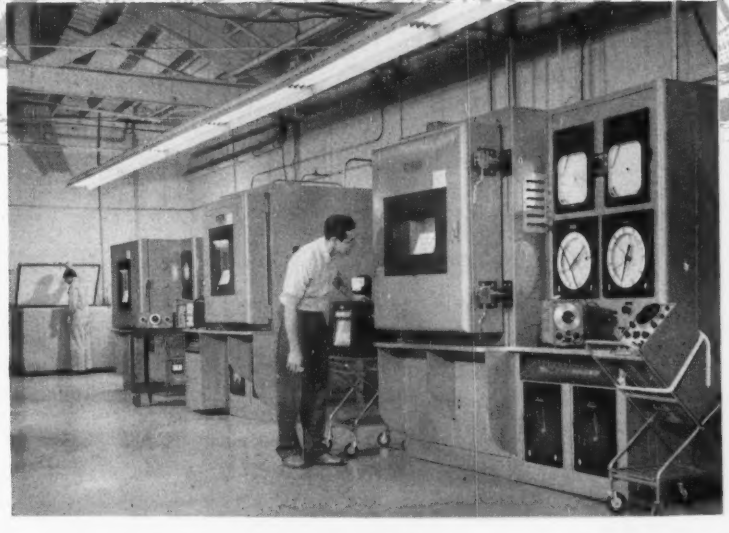

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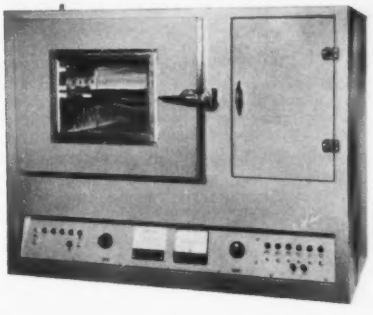

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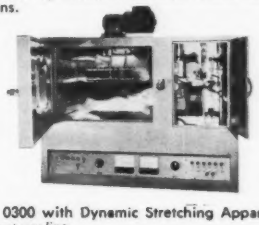

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A SYNOPSIS OF NATURAL ENVIRONMENTS TO HEIGHTS OF 1000 KM

by A.P. HARRIS & E.W. PARROTT

SUMMARY

All environments vary with time, some slowly and imperceptable, others with a speed that is difficult to record. The rhythm of variation is for the most part dependant on changes in location with respect to the sun and the two principal cycles are therefore daily and by-yearly.

Surface conditions are not conditions encountered at altitudes. To define an earthly environment accurately therefore requires three dimensions in space and one in time. Some conditions can be represented for design or simulation purposes by a mean or representative value and a time factor. Others are practically indefinable by this means and perhaps may require a statistical summation or broad band approach analogous to the method of complex wave vibration testing.

Fortunately the work undertaken by all the nations participating in the International Geophysical year will probably define these conditions and add much to what is known. The time lag in applying this knowledge will probably be considerable as a vast amount of information must be digested, assessed and reported. More time will be involved before the data influences our testing methods or standards.

It seems to us that our testing methods have preceded in some cases the standardization of the conditions we are trying to duplicate. The logic of the reverse procedure is inescapable. Further, our tests are not really simulating the natural environments but are extrapolated too far in intensity.

A. INTRODUCTION

In the atmosphere that surrounds the earth there are many environments visible and invisible, mild or destructive and of various degrees of importance to military designers.

These are conditions which the environmental test engineer is called upon to simulate in his laboratory - with only moderate success in many cases as the phenomena that nature produces casually can be achieved synthetically only by considerable effort and expense.

They are, however, the target and it is worthwhile to stop and look at these conditions again particularly as new information is being added which may modify our old methods and add new objectives for simulation.

To review each natural environment in detail is a task beyond the intent of the article. This is a synopsis of primary features. Nor can we give you the intricasies and theoretical background that would satisfy the physicists. This is an engineer's approach to the problem.

We are considering only the free natural environments and not those which are a function of the man made vehicle. Mechanical shock, vibration, explosive conditions and such conditions are excluded.

We hope to present you with a summary of the earth's environments and to mention their nature, their magnitude, their variation with altitude and their inter-relation.

Further we are not dealing with animal life or submarine conditions.

Our environments fall into three main categories, Atmospheric Solids, Atmospheric Gases and lastly the conditions involving Fields, Radiant Energy and Particles. As electromagnetic phenomena are not usually listed as classes of environments you may ask why they were included. The answers are that firstly the picture is not complete without them; secondly it is impossible to consider some physical environments accurately in the absence of these conditions; and thirdly some field, radiant and particle conditions are just as annoying and just as difficult to design around as the more common environments.

If you notice some areas that seem indefinite in this article it is not only because this article is derived from "unclassified" material, in many cases science does not yet know the complete answer.

B.1 SEA WATER

The existance and configurations of the oceans of the earth are well known to all of you so that only a brief mention of the most noteworthy properties is necessary.

Of greater importance is the maximum depth, 18,000 ft., and the corresponding pressure, 75,000 lb/square inch. This enormous pressure, of great concern in the field of submarine cables, and vehicles exists on account of the weight of sea water above this level. Sea water has a density of 1.025 times that of water, the extra density being due to the dissolved particles, a typical analysis of which is given in Fig. 1.

Practically all known elements are found to some degree in water and there are, in addition considerable quantities of dissolved gases, particularly carbon dioxide.

The temperature at extreme depths is only just above freezing whilst nearer the surface temperature can be considerably higher according to geography and season.

Due to the excess of strong basic ions, sea water is normally slightly alkaline, with a pH value between 8.1 and 8.3. However the removal of carbon dioxide by photosynthetic processes in marine plants can result in an increased value of pH as great as 9.7.

The most destructive effect of the presence of these salts lies in the ease with which galavanic and concentration cells may be formed with their well known corrosive effects.

TYPICAL ANALYSIS OF ELEMENTS PRESENT IN SOLUTION IN SEA WATER EXCLUSIVE OF DISSOLVED GASES — FIG. 1

Element	Parts/Million	Element	Parts/Million
Chlorine	18980	Copper	0.001-0.01
Sodium	10561	Zinc	0.005
Magnesium	1272	Lead	0.004
Sulfur	884	Selenium	0.004
Calcium	400	Cesium	0.002
Potassium	380	Uranium	0.0015
Bromine	65	Molybdenum	0.0005
Carbon	28	Thorium	0.0005
Strontium	13	Cerium	0.0004
Boron	4.6	Silver	0.0003
Silicon	0.02-4.0	Vanadium	0.0003
Flourine	1.4	Lanthanium	0.0003
Nitrogen *	0.006-0.7	Yttrium	0.0003
Aluminum	0.5	Nickel	0.0001
Rubidium	0.2	Scandium	0.00004
Lithium	0.1	Mercury	0.00003
Phosphorous	0.001-0.10	Gold	0.000006
Barium	0.05	Radium	$0.2\text{-}3 \times 10^{-10}$
Iodine	0.05	Cadmium	present
Arsenic	0.002-0.02	Cobalt	present
Manganese	0.001-0.01	Tin	present

* Nitrogen in combined forms.

Sea water is the principal source of atmospheric humidity leading to clouds, rain, snow and ice. It has a moderating effect on coastal temperatures.
(Reference – 28, 29)

B.2 SALT SPRAY

As a result of the action of breaking waves and high winds fine particles of sea water are picked up from the sea and carried into the atmosphere as a unit or fog. Some of the water in these particles evaporates and leaves minute particles of the dissolved salts in a fine enough state of subdivision to be suspended in the air. These mists or fogs, composed of both wet and dry particles can extend inland for many thousands of feet and have even been detected up to 10 miles inland and at altitudes of 20 Km.

The greatest concentrations are, however, within a 1000 feet of the above and below 152 meters (500 ft.). *(Ref. 32)* Particles of salt may even be borne up to heights of 82 Km to form condensation nuclei for clouds of ice crystals.

The size of condensation nuclei are shown subsequently.
(Reference – 26, 27, 30, 31).

B.3 FOG AND CLOUDS

Although salt particles form excellent nuclei for condensation, as will be described later, these are not the only source of nuclei and fogs and mist occur in their absence when the temperature and dew point of air, having a high moisture content and a supply of hygroscopic nuclei, become identical. These conditions occur most frequently when cold air exists above warm, moist soil. The hot ground vapours are then condensed by the colder air after first saturating the colder air.

If a mist so formed becomes mixed with smoke it then assumes a colour, depending on the colour of the smoke.

Mists can occur at greater altitudes and are then referred to as clouds. These are of three classes.

Common Clouds, comprising water droplets immersed in air, both being above freezing point.
or *Supercooled Clouds*, where the air is at, or below, freezing point.
or *Ice Crystal Clouds*, comprising tiny ice crystals suspended in air, both crystals and air being below freezing point.

Derived from their appearance and properties a more descriptive classification is sometimes used:–

CIRRUS CLOUDS

These occur at a mean altitude of 9,700 Km (32,000 ft.) and are composed entirely of ice crystals.

STRATUS CLOUDS

These are encountered at altitudes from a few hundred meters up to 910 Km (3000 ft.).

CUMULUS CLOUDS

These usually occur between 910 Km (3000 ft.) and 1820 Km (6000 ft.).

CUMULI–NIMBUS CLOUDS

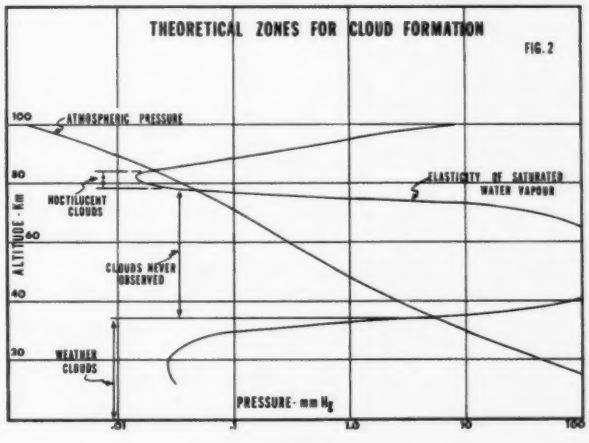
These can extend up to 15,100 Km (50,000 ft.) and contain rain, snow, hail and lightning.

Much has been written on this subject and it is not proposed to elaborate on the details given except to point out that clouds are obviously regions of saturated or super-saturated air and need not be homogeneous. The mean water content of clouds is 0.3 to 1.0 grams/cubic metre although a maximum content of 5 grams is possible. The mean diameter of the droplets in clouds is 2 to 20x10–4 cms. so that only one millionth of the volume of a cloud is water.

The source of water vapour for high humidities, mists and clouds is principally the sea surfaces from where it is swept upwards by vertical winds.

In the category of clouds comes the phenomenon referred to as Noctilucent clouds. These clouds, visible at night with a luminosity of 0.4 candles per square centimeter, are at a constant height of 82 kilometres and cover vast areas of the order of tens of thousands of kilometres square. They are composed of tiny ice crystals and travel at speeds up to 200 metres per second and always greater than 15–20 metres per second. The most probable mode of formation of these clouds is by direct combination of hydrogen in the particle streams from the sun, with dissociated oxygen molecules. From the analysis of the light spectrum the presence of sodium is very noticeable by the emission of the D lines of the spectrum. The presence of sodium is due to the powerful temperature inversion in this region which prevents the particles of salt from breaking through, causing them to accumulate at this altitude, and allows the particles to act as condensation nuclei.

The physical explanation of this phenomenon is shown in Fig. No. 2



Clouds can only be formed when the atmospheric pressure exceeds the elasticity value for saturated water vapour. Due to the temperature and pressure variations in the atmosphere, the elasticity is the smaller only below an altitude of 33 kilometres and in the region of 79 to 84 kilometres. Thus only in these regions can clouds be formed and these correspond to the weather clouds and noctilucent clouds.
(Reference – 26, 36, 31, 32)

B.4 RAIN, SNOW AND ICE

As the atmosphere is constantly taking up moisture to maintain a dynamic equilibrium it must reject some of the moisture absorbed. This it does in the form of rain, snow and ice, a phenomenon familiar to all of you.

Some of the water is rejected in the form of rain drops of sizes up to 7 millimetres according to their history of formation and height of fall. The median diameter (D) in millimetres of the drops in a shower of intensity 1 inches per hour is given by the expression,

$$D - 2.23.\ I^{.182}$$

and the standard deviation, S_D, is estimated by the formula

$$S_D = .53 \log I.$$

which gives a standard deviation of 1 millimetre for an intensity of 7 inches per hour.

The terminal velocities of different size rain drops and the equivalent free fall height are given in Fig. No. 3. The maximum free fall height at 4 millimetres is due to the tendency of larger size drops to remain spherical in the first stages of fall, thus offering less cross sectional area to the passing air and hence attaining higher velocities than would be consistent with their final shape.

Impurities occur in rain in varying amounts up to 430 parts per million and consist mostly of dissolved and combined oxygen, nitrogen, and carbon dioxide. Nitrogen occurs as nitric acid, ammonia and nitrates, these being formed by lightning discharges.

The maximum concentrations of impurities occur near the sea due to the effects of salt spray mentioned earlier. In towns rain may contain comparatively large concentrations of sulphurous acids.
Reference – 10, 26, 36)

Not all the moisture rejected by the atmosphere reaches the ground in liquid form. Much becomes frozen and appears as snow, ice, sleet, or hail, and contamination from the same impure atmosphere produces the same types of impurities as rain. In the case of snow this deposit can accumulate and produce a loading on surfaces up to 800 lbs/square inch, corresponding to 12 feet of compact snow. The greatest falls of snow (i.e. the greatest snow load potential) have occurred in the Arctic regions, defined as regions where temperatures of −40°C have been observed. These large snowfalls usually appear when the air temperature is just below freezing point.

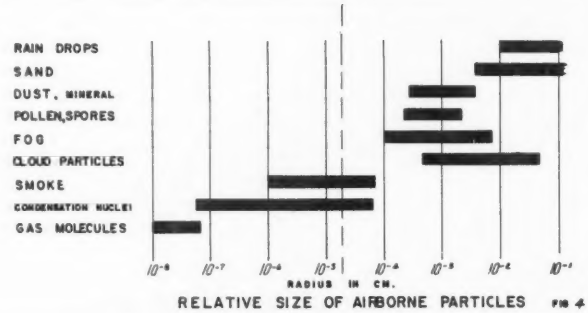
The actual snow crystals vary from less than 1 millimetre to 1.5 millimetre but snow flakes can be up to 15 inches by 8 inches.

When the moisture of the atmosphere is precipitated as sleet the usual grain size is up to 0.16 inches diameter and is formed by the freezing of rain drops. But hail, which is normally composed of balls or irregular lumps of ice between .08 inches and 0.2 inches diameter, can be as large as 5 inches diameter and weigh 1½ lbs. These large 5" diameter hail stones require the existence of upward currents of air of speeds around 200 m.ph and a 3 inch diameter stone requires a 100 m.ph current for its formation.

FIG. 3

RAIN DROPS, SIZE, TERMINAL VELOCITY AND FREE FALL HEIGHT

Drop Size Diameter (millimetres)	1	2	3	4	5	6
Terminal Velocity (metres/sec.)	4.8	6.6	8.1	8.9	9.25	9.3
Free Fall Height For 95% of Terminal Velocity (metres)	2.2	5.0	7.2	7.8	7.6	7.2



RELATIVE SIZE OF AIRBORNE PARTICLES FIG 4

Obviously, to design against this last environment is wasteful and usually unnecessary.
(Reference –10, 26)

B.5 SAND, DUST, SMOKE

A great many varities of solid particles exist in the atmosphere. These include, to various degrees, wool, cotton and other hair like particles, plant pollen and spores, carbon, ash, minerals, salt, glass and a variety of cosmic particles. Their origins are the earth, the sea and outer space. From land sources their origins are both natural and man-made, from the dust, of a dry field, and volcanic eruption to the smoky chimney and the automobile.

Their geographic distribution is obviously extremely variable and there is as well a daily and seasonal variation depending on the location.

By definition a sand particle is one greater than $4x10^{-3}$ cm. in radius and dust particles are less than $4x10^{-3}$ cm. radius.

The relative sizes of these and previously mentioned solids are shown in Fig. No. 4.

Mineral and inorganic dust particles are usually angular in form and abrasive. They may also be hygroscopic. Most airborne plant particles are hairlike while spores are usually spherical.

The dotted line in Fig. 4 shows the limit of optical visibility. Condensation nuclei are particles in either liquid or solid form upon which moisture condenses to form droplets. Their size runs from $7x10^{-5}$cm. radius and is shown in comparison with the size of gas molecules.

Their presence has a considerable bearing in fog, cloud and rain conditions. Without them there is no rain.

The concentration of dust, sand and smoke is widely variable.

The concentration of smoke and other particles varies widely.

Over rural areas there may be 5000 particles/cubic inch, over small cities 50,000 and over major industrial 500,000 particles per cubic inch.

Their distribution with Altitude is as follows:–

Sand – (as defined) a few feet.

Dust & Smoke – to 10,000 feet.

Condensation Nuclei – to 10 Km and possibly 82 Km.

(Reference – 10, 13, 26, 30, 31)

B.6 FUNGUS AND BACTERIA

Fungus are members of the plant family, but one of their principal differences from normal plants is that they lack chlorophyll and are unable to gain sustenance from the air by photosynthesis processes. Plants are able to convert CO_2 from the air into a usable carbon form by the action of light in their chlorophyll. Fungus must gain sustenance by decomposing living or inert organic substances. In certain cases the growth of fungus results in the evolution of citric, oxolic or other organic acids but most species give off CO_2 only. Fungus are thread like in shape and reproduce by spores which compare with the seeds of ordinary plants. Their relative dimensions were shown in Fig. 4. Small non-parasitic fungus are called molds.

Bacteria are simpler in structure, often single celled. Most are able to carry on photosynthesis. They reproduce by division of their cells and in many cases produce a hardy spore within the individual bacteria cell.

Moulds, fungus and bacteria are more common and active in tropical and temperate areas than at the poles where conditions for growth are less favourable. They occur within the soil and spores and bacteria because of their size may be carried to several thousands of feet.

The most favourable environmental conditions for growth are shown in Fig. 5.

From these factors it is apparent, and is known, that polar areas are most free from fungus and bacteria. It might also be deduced that the extremes of temperature and high solar radiation at very high altitudes would destroy most fungus and bacteria although it has been stated that very hardy forms might exist even in outer space.

(Reference – 23, 24, 26)

B.7 METEORS AND METEORITES

Meteoric particles originating in space strike the earth's atmosphere at tremendous speeds and within seconds the particles are heated to boiling point by air friction and completely evaporated within seconds; giving off a bright light in the process.

Incandescence usually takes place between 60–120 Km, extinction as low down as 30 Km.

The daily deposit on the earth has been estimated at: $10^8 - 10^9$ grams of meteoric dust.

The "shooting stars" are pea sized meteorites. It is estimated that 75 million particles above five thousandths of an inch in diameter enter the earth's atmosphere every day.

The residue left from meteor evaporation settles slowly down through the atmosphere. This residue may act as condensation nuclei or as a catalyst for some of the photo chemical processes which occur in the upper atmosphere.

(Reference – 5, 31, 36)

FIG. 5

ENVIRONMENTAL CONDITIONS FOR FUNGI & BACTERIA

		MOST FAVOURABLE	DESTROYED
Moisture Content of Nutrient	- Fungi	8% Up	
	- Bacteria	10% to 100%	
Moisture Content of Air	- Fungi	70 - 100% R.H.	
	- Bacteria	70 - 100% R.H.	
Temperature	- Fungi	10°C to 38°C	90°C - 20 mins
	- Bacteria	10°C to 38°C	90°C - 20 mins
Light	- Fungi	Not Required	Strong Ultra Violet
	- Bacteria	Not Required	Strong Ultra Violet
Oxygen	- Fungi	Required	
	- Bacteria	Not Required	
PH Range	- Fungi	4 - 7	
	- Bacteria	7 - 8.5	
Nutrient Elements Req.	- Fungi	C, H, N, S, K, Mg, P plus trace elements.	

FIG. 6

CONSTITUENTS OF AIR AT SEA LEVEL

CONSTITUENT		PERCENT	MOLECULAR WEIGHT
Air		100	28.966
Nitrogen	N_2	78.08	28.016
Oxygen	O_2	20.95	32.00
Argon	A	0.93	39.944
Carbon Dioxide	CO_2	0.03	20.183
Neon	Ne	0.0018	44.010
Krypton	Kr	0.0001	20.183
Helium	He	0.00053	83.7
Hydrogen	H	0.00005	4.003
Xenon	Xe	0.000008	131.3
Ozone	O_3	0.000001	48.00
Radon	Rn	6×10^{-18}	222
Water Vapour		0.00001	-
Sand, Dust, Smoke			

C – GASES

C.1.1 Constituents

Enveloping the solid airborne particles we have mentioned are the atmospheric gases. All gases are said to have been exuded from the earth's mantle or second layer.

At sea level the constituents of the atmosphere are shown in Fig. 6.

The principal gases are nitrogen, oxygen, argon and carbon dioxide, all the remainder total about .01%. Water vapour is added to complete the list.

It has been indicated *(Ref. 11)* that the relative constituents remain reasonably constant to 150 Km and the lighter elements do not settle out in layers.

We say reasonably constant as changes do occur within this region. The percentage of ozone increase to a maximum at about 21 Km; Oxygen changes from a molecular form to an atomic form starting at about 80 Km. These effects are both due to solar radiation. The absolute humidity also decreases rapidly and is of a very small order above 80 Km.

In the extreme altitudes other transformations take place. There is evidence for the dissociation of nitrogen N2 into atomic forms.
(Reference – 6, 11, 26, 37)

C.1.2 Molecular Weight

The dissociation of oxygen begins at about 80 Km and nitrogen at about 150 Km. Dissociation occurs because of the effects of energy from solar radiation of short wave length. The rate of dissociation of oxygen is about 100 times that of nitrogen. The effect occurs to a much less extent at lower altitudes as the radiation in the higher frequencies has been largely absorbed by the upper atmosphere. This is not a one-way process. Recombination of oxygen atoms takes place and various combinations of oxygen and hydrogen atoms may reform.

The recombination is faster at low altitudes because of the greater density and the shorter path before two atomic particles may collide. At high altitudes for converse reasons they do not recombine very rapidly.

The combined effect on the mean molecular weight of the atmosphere is shown in Fig. 7.

This curve drawn from two sources *(Ref. 11 and 4)* shows a constant molecular weight of 28.8 to about 80 Km where an abrupt change takes place leading to a molecular weight of 25 at about 130 Km and decreasing to about 16 at 400 Km.

These changes are significant for investigators in this region, both theoretically and experimentally, as calculations based on classical gas laws must be adjusted accordingly and measurements are affected particularly where these measurements are not made directly but are derived from other measured properties of the atmosphere. (Such as the determination of temperature from measurements of pressure and density.)
(Reference 4, 11, 19).

C.1.3 TEMPERATURE

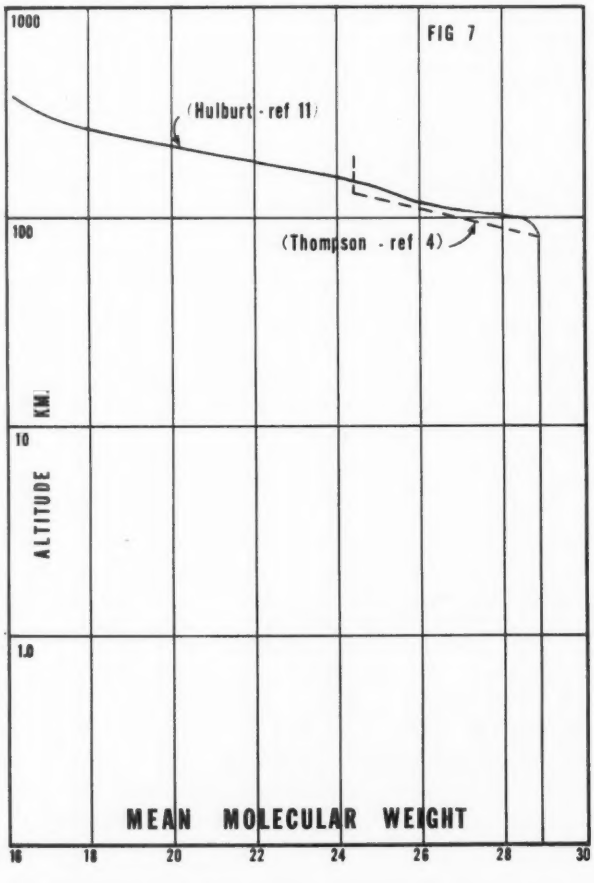
Both earth surface temperatures and air temperatures up to the limit of the atmosphere are direct functions of the amount of solar radiation received by the earth. The temperature varies daily, seasonably and with geographic location due to the earth's rotation and angle of inclination and it's distance from the sun. There is a complex phenomena involving absorption and radiation effects of the earth and various constituents of the atmosphere which largely determines the temperature at any given place and time.

Surface temperatures over the earth have reached extremes as low as minus 79°C (–102.2F) and as high as 60°C (+140°F). It is convenient to and for their areas representative mean temperatures are as follows:

Temperate	25°C
Polar	5°C
Tropical	32°C
Desert	40°C

Typical daily and seasonal variations in this area are as follows:

	Daily Variation	Seasonal Variation
Temperate	11°C	32°C
Polar	–	83°C
Tropical	1.6°C	17°C
Desert	17°C	45°C



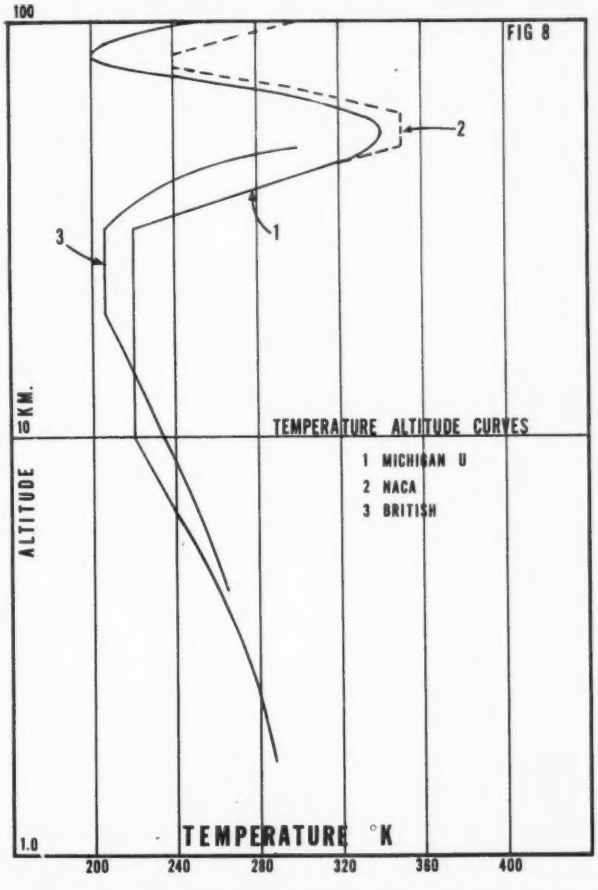
We have not included the sea as a specific area as it is not as definable as the others mentioned while the sea water temperature is reasonably constant over large areas and while it has a moduating effect on surface air temperatures its geographic coverage is too wide for easy classification. Sea surface air temperatures have been recorded from 45°C (113°F) to minus 40°C (–40°F). The daily variation runs about 5.5°C (10°F) except in polar areas.

Changes in temperatures with increasing altitude are shown in Fig. 8.

These curves are a few of the many measurements and theoretical calculations which have been made of temperature in the upper atmosphere. While they disagree

in magnitude they have a common shape and a common theory is accepted for the shifts in direction of the temperature.

At the low levels the air picks up heat by actual contact with the warm surface and by long wave or infra–red radiation from the earth. This radiated energy is absorbed by carbon dioxide, ozone and water vapour but is almost immediately re–radiated. Below about 20 Km the energy lost by re–radiation is greater than the energy absorbed and there is a steady drop in temperature of about 6.5°C for each Km rise. This is varied by local



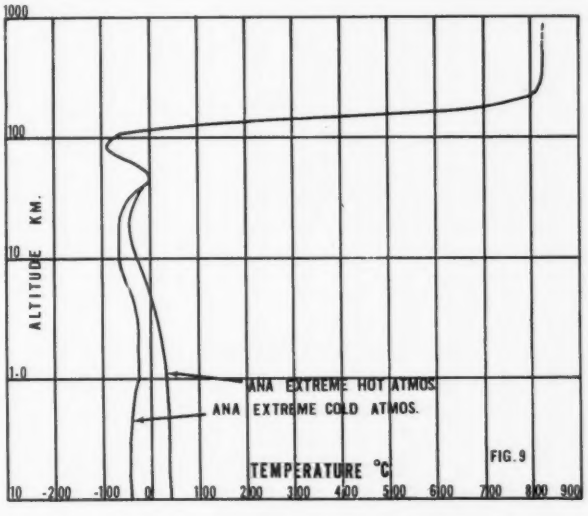
weather conditions and the geographic location. The rate of decrease is more rapid at the equator than at the poles due to different humidity conditions. The change in direction is explained by the absorption of solar energy by ozone at 1 ultra–violet frequencies.

This energy is emitted at a higher altitude depending on the carbon dioxide and ozone present resulting in a temperature peak at about 50 Km. The energy at ultra–violet freq. absorbed by ozone above its peak concentration is greater than the energy radiated at infra–red frequencies by water and carbon dioxide.

As the ozone concentration decreases the energy radiated exceeds the intake and the temperature drops again to a low at about 80 Km.

Above 80 Km dissociation of gas molecular and ionization occurs increasing the number of particles and making the air conductor. Then a large amount of solar radiation is absorbed and the temperature increases rapidly with height.

The tolerances on this curve which depend on geography, etc., can be simplified and Fig. 9 is a proposal to this end.



The two legs are the NACA Standard extreme hot and cold atmospheres, trimmed off at about 40 Km.

The changes in temperature gradient are shown by the dotted line.

The succeeding upper portions of the curve cover both the proposed WADC Standard atmosphere proposal to about 70 Km and the latest known NRL theory above this point. The curve above 70 Km assumes certain conditions including a certain composition of the atmosphere, dissociation of oxygen and nitrogen and certain particle densities.

"The rapid rise above 200 Km was chosen to satisfy the conditions that the loss of energy by conduction downward would be about the same as the energy received from the absorption of ultra–violet and infra–red in the high levels".

The variation of temperature daily and seasonally are not yet clearly known. Daily changes of about 5°K at about 45 Km and 1°K at 70 Km are proposed by one author *(Ref. 11)* and seasonal changes of 300°C at 200 Km and 700°C at 400 Km by others *(Ref. 1, 6)*.

There is evidence based on the constancy of the E layer between day and night that the daily changes below 10 Km is less than 10°K.

Above about 50 Km the temperatures shown have not the same significance that the environmental engineer is normally used to. The air density and the number of particles present becomes so low that heat conduction and conviction do not apply. The temperatures are without real heat and are representative more of the velocity of the air particle.

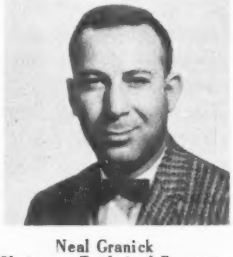
To be continued in the August Issue

HIGHLIGHTS OF THE 1960 NATIONAL MEETING

APRIL 6-7-8-9
LOS ANGELES, CALIF.

Appreciation is due William Vandal as Convention Chairman for coordinating the activities of the various Chairmen from the Los Angeles Chapter, and to Neal Granick for the preparation of a thorough and informative Technical Program.

William L. Vandal
Convention Chairman



Neal Granick
Chairman, Technical Program

The technical sessions registration and exhibits were capably handled by the following committee members.

Jerome Bakalish
Convention Treasurer

Bruno J. Forsher
Chairman, Exhibits, Booth Arrangements

Floyd Ben Squires
Chairman, Technical Meetings and Facilities

Other committee members who helped make the meeting a success were: MARK S. CHRISTENSEN, Chairman, Convention Publicity; ROBERT SHAIDNAGEL, Chairman, Outside Program; CHARLES W. DANIELSON, Editor, Journal of Environmental Sciences.

The 1960 Meeting theme was "Hyper–Environments – – Space Frontier", which was indeed a timely and up-to–date topic. This theme had generated many informative and provocative Technical Papers.

Parallel sessions were on subjects which differed widely enough so that all different groups of people would be interested in the different sessions.

All of the Papers formally presented in the Technical Sessions were included in the copy of the Proceedings. Thus attendees could read those Papers of special interest prior to their presentation and participate in the discussions.

This year manufacturers were asked to provide the unusual or the very new for exhibit at the meeting. Their technical personnel were available in the booths to discuss with attendees any problems which they might have pertinent to the various types of equipment.

LESLIE BALL addressing the first day luncheon.

Past President, HAROLD JONES, addressing attendees at the Keynote Assy.

NEAL GRANICK, Program Chairman, addressing the first day luncheon.

BRUNO FORSHER, Exhibit Chairman, and one of the many Military Exhibits.

HAROLD JONES tuming over the Presidency to WILLIAM VANDAL.

Retiring Board Members RAYMOND YAEGER, V.P. Publications, WILLIAM VANDAL, Exec. V.P., ART BILLET, Fiscal V.P., and HAROLD JONES, President.

Newly Elected Officers of the I.E.S.

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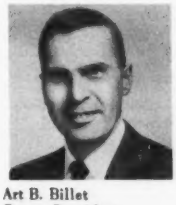
President



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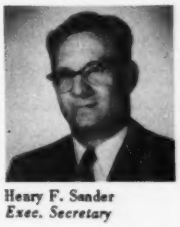
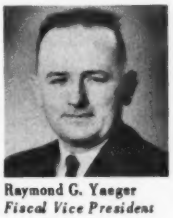
Exec. President

Russell Lowe
Publications Vice President



Henry F. Sander
Exec. Secretary



Raymond G. Yaeger
Fiscal Vice Presidents

Leon D. Carver
Membership Vice President

Harold C. Jones
Ex-Officio

John Regazzi
Local Chapters
Vice President

THE PRESIDENT'S CORNER

WILLIAM L. VANDAL

On Wednesday, April 6th, the 1960–61 Officers of the Institute of Environmental Sciences held their first Executive Committee meeting. I would like to express my thanks and appreciation and those of the Institute to the outgoing Officers for an excellent job, well done. As you new President, I intend to continue to further the goals of our organization, so well stated by *Harold Jones* in the April issue. They are: to keep the institute on a firm financial basis, improve communications between officers, chapters and members, and to raise the professional status of the Institute and its members.

Probably the most important step taken by your new Executive Committee was to place our Executive Secretary, *Mr. Henry Sander*, on a full time basis as a paid employee of the Institute, to operate our national office in Illinois. Many of the problems concerning delays in processing membership applications, obtaining complete membership lists, etc. were just not solvable with our previous part time office. With a full time staff and office, we hope to provide a more business-like approach and a better organization. The mailing address of our new office will remain the same: Box 191, Mt. Prospect, Illinois.

Your new Executive Vice President, *Art Billet*, will be this year, as I was in 1959, General Chairman of the National Meeting. The 1961 meeting will be held April 5, 6 and 7 at the Sheraton-Park Hotel, Washington, D.C.

The new Fiscal Vice President is *Ray Yaeger*, who was Publications Vice President last year. The important job of working with *Chuck Danielson*, Technical Editor, to publish the Journal and the coordination of our other publication activities is now the responsibility of *Russ Lowe*, who did an excellent job as Membership Vice President last year. The new Membership Vice President is *Leon Carver*. The new Local Chapters Vice President is *John Regazzi* and, of course, the Past President is *Harold Jones*. As mentioned above, *Hank Sander* will continue as Executive Secretary.

The 1960 National Meeting held in Los Angeles is now history. It was bigger and better than ever. Total attendee registration was 935. There were 80 booths in the exhibit hall. Based on comments received from the exhibitors, the exhibits were well patronized and successful in showing those who attended the meeting the latest and newest in environmental facilities and hardware. Financially, the Institute profited from the meeting. This will help us to operate our new national office and perform more services for the members. A notable achievement was the preparation of the "Proceedings" by *Neil Granick*, Chairman of the Technical Program, and his Committee, in advance of the meeting. This 678 page volume was distributed to the attendees as they registered. It contains complete reprints of the 66 excellent technical papers presented during the three day meeting. Additional copies of individual reprints and the Proceedings are available at our Chicago office. Proceedings are on sale for $12 to nonmembers and $8 to members. Reprints are fifty cents each.

The Institute now has ten active Chapters. IES members in Dallas/Ft. Worth, Minneapolis and Seattle are also holding preliminary organization meetings preparatory to formation of new chapters. The year ahead, by present indications, will be a busy one for all of us in the environmental sciences. Our organization, its professional stature and accomplishments are dependent on its individual members as well as its officers. Your new officers pledge to do their best; you as members can help by boosting your local chapters and the Institute and by your own active participation.

W. L. Vandal

NOTES FROM THE EDITOR

CHARLES W. DANIELSON
TECHNICAL EDITOR

Our society recently concluded a national meeting in which the equipments displayed and the technical papers presented were of significance to all persons active in the field of environmental sciences.

Means of obtaining copies of the 1959 and 1960 proceedings or reprints of the papers is mentioned in another section of the Journal. Brief abstracts of the various papers will be listed in the *Technical Information* section of each issue of the Journal for interested persons and those who could not attend the meeting.

I would like to mention again that the Journal is interested in publishing articles related to the environmental sciences. In particular we would like the articles to disclose new developments in the field or parallel and update previous articles or papers.

Continued on page 27

DEVELOPMENT OF A COMBINED CLIMATIC, STATIC, AND DYNAMIC ENVIRONMENTAL TEST FACILITY

by

J.J. Hendrix
E.H. Moore
K.M. Murphy

NORTH AMERICAN AVIATION INC.
MISSILE DIVISION

ABSTRACT

North American Aviation, Inc., Missile Division Testing Laboratory's capability for combined environmental testing has long permitted the combination of climatic environments such as temperature, altitude, humidity, etc. The Laboratory has employed this capability effectively in numerous ways without ever seriously considering the addition of both vibration and linear acceleration to extend the capacity for testing under multiple environments. Some eighteen months ago, however, the Laboratory received several inquiries, including one from USAF BMD, as to its capability for testing under combined sustained inertial and vibratory loading. Pursuit of these inquiries revealed a strong indication that such combinations of environments are to be significant in future missile and aircraft development testing. An adequate capability for such combined testing therefore appeared to be desirable, and means for acquiring this capability were considered. It is the purpose of this article to outline factors which entered into this consideration, to describe design and development of the facility, and to indicate the degree of capability achieved.

CONSIDERATION OF FACILITY DESIGN:

The combination of vibration and sustained acceleration can be obtained in two ways. First, by placing an accelerator on a vibrator, and second, by reversing the process and providing some method of vibration excitation on the accelerator. Consideration of the methods stated above was governed by the following design precepts:

1. Existing equipment was to be utilized.
2. Development cost was to be held to a minimum.
3. Facility was to be available for use in six months.
4. Facility capability to be 25 g's in the frequency range 25–2000 cps, with 15 g's of sustained acceleration, additive.
5. Equipment used was to retain its capability for general use.

A survey of existing test equipment based on the above design precepts dictated that the means of vibration excitation should be mounted on the accelerator. No decision was required relative to providing linear acceleration since only one piece of equipment suitable for this application was available; a Genisco Model C–159 accelerator.

Conversely, several possible means of providing vibration excitation were considered. Mechanical methods of excitation were available but their use was rejected due to their limited range of frequency. Resonant beams were attractive from the standpoint of weight but the number required to fully cover the frequency range was considered excessive and they were also rejected. It was decided that the most practicable means of providing vibratory excitation would be the conventional electrodynamic shaker, and design consideration proceeded upon this basis.

Since the source of sustained acceleration was to be a Genisco Model C–159, its capability was evaluated in terms of the design precepts. A preliminary static and dynamic analysis of the accelerator beam led to the following observations:

1. The manufacturer was conservative in rating the capacity of the accelerator.
2. Additional beam torsional stiffness was required for compatibility with anticipated requirements.
3. The beam would not withstand the expected dynamic test loads.
4. The moment acting through the c.g. of the exciters accounted for greater than 90% of the total moment.

As a result of the above analysis, it was concluded that the accelerator beam would need to be stiffened or, alternatively, that there would need be provision to counteract the dynamic load. This latter alternative was selected in the expectation that it would entail the expenditure of less time and money. During test, the accelerator required both static and dynamic balancing, so the decision was made to mount two identical, dynamically opposed shakers on the accelerator beam. The MB Model C–6–C shaker was found to satisfy basic problem conditions of size, weight, force output, and frequency range. Additional considerations which influenced the selection of this type shaker include an advantageous "force output to mass" ratio, a wide frequency range (5 to 5000 cps), and electrical requirements which were compatible with the rated capacities of the silver alloy slip rings provided on the accelerator.

The selection of the C–6–C shaker limited test specimen gross weight, exclusive of the armature table, to approximately five (5) pounds. Heavier specimens reduced vibration levels below the required 25 g maximum. A sketch of the accelerator–vibrator combination is shown in Figure 1.

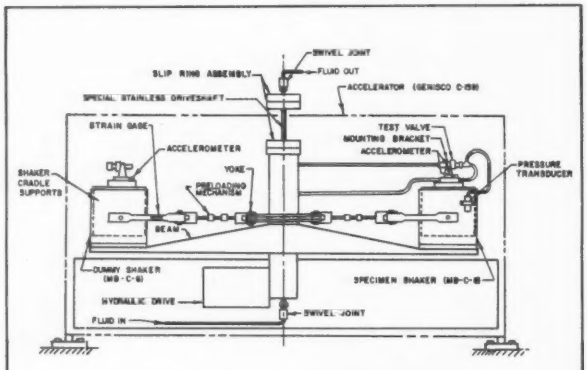


FIG. 1 CONFIGURATION OF COMBINED ENVIRONMENT TEST.

With decisions regarding equipment selection accomplished, attention turned to ways of putting the equipment to optimum use. Orientation of the vibration exciters on the accelerator beam and incorporation of provisions for climatic environments were primary considerations in this new decision phase.

Standard procedure for the combination of vibration and sustained acceleration in orthogonal axes usually includes exposure in all orientations. As previously mentioned, however, analysis showed the accelerator beam to be weak in torsion, and for this reason it was not considered advisable to vibrate in the axis tangential to accelerator rotation. Therefore, two axes of vibration with respect to the axis of sustained acceleration were chosen, namely, the axes normal to and coaxial with that of linear acceleration. Any disadvantage arising from the elimination of tangential vibration was expected to be offset by careful consideration of component symmetry in fixture design.

Because of space and weight limitations, it was found necessary to restrict means of imposing climatic environments to the simplest form possible. The means evolved consisted simply of wrapping conventional insulation material around the test specimen and permeating this material with heating or cooling fluid, as the case demanded. Space limitation further dictated that hot and cold fluid be stored outside the accelerator and be piped through swivels to the desired area of heating or refrigeration. Some additional modifications of the accelerator were found to be required to perform this function but initial planning proved the feasibility of the general scheme.

EQUIPMENT MODIFICATION AND DESIGN:

Removal of the accelerator optical system and replacement with 3000 psi stainless steel lines and swivels for conveying climatic control fluid was one of the first accelerator modifications. Some difficulty was experienced with performance of swivels in this service and the problem demanded specific design effort for solution. An outgrowth of this effort has been a superior swivel, which cannot be discussed in this article because patent protection has not yet been obtained. It will suffice to say that the resultant system has proven to be highly satisfactory.

Other modifications made to the accelerator included raising of the protective enclosure sides (See Figure 2), reinforcement of the beam to increase torsional stiffness, and the replacement of manual operation with servo control. Additional slip rings were installed to permit more extensive instrumentation, and the wiring was changed to allow operation at higher temperatures. The change to remote control was made necessary by the Laboratory Safety classification of the facility as "dangerous."

As far as structural integrity of the vibration exciters was concerned, no major problems with the 15 g sustained

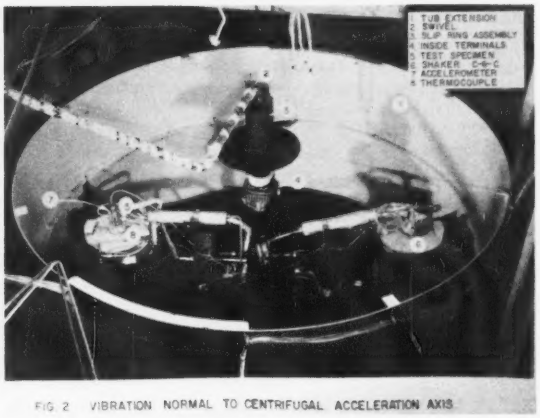


FIG. 2 VIBRATION NORMAL TO CENTRIFUGAL ACCELERATION AXIS

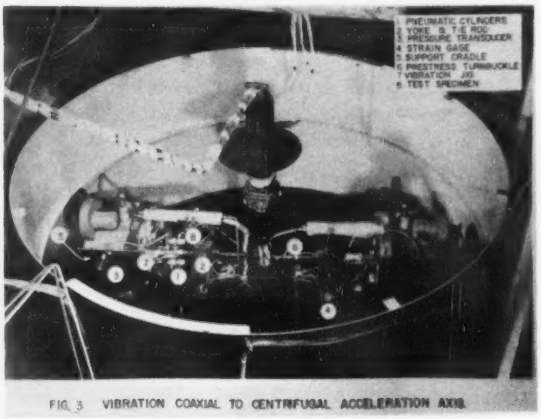


FIG. 3 VIBRATION COAXIAL TO CENTRIFUGAL ACCELERATION AXIS

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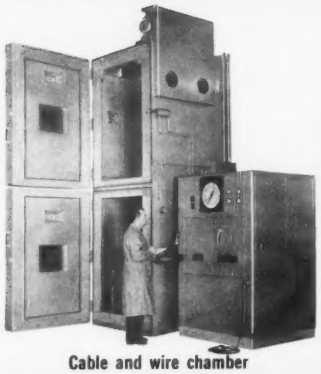
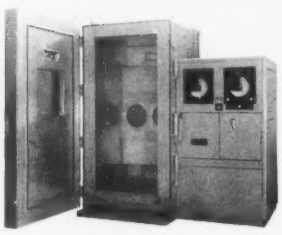
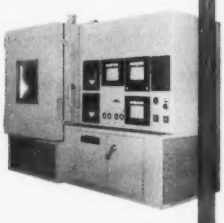


Cable and wire chamber

Oil viscosity test units



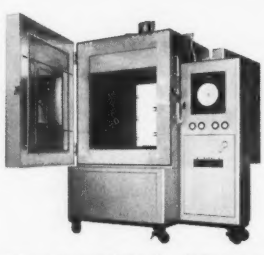
Relay rack test unit



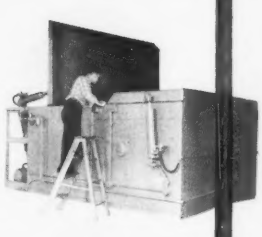
400,000 ft. altitude test cham

Explosion test chamber

Large altitude chamber



"Pass through" double duty units



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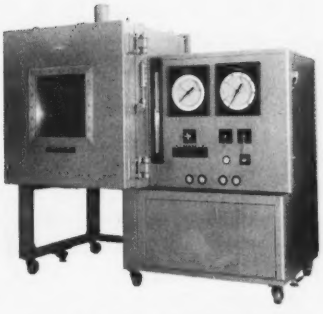
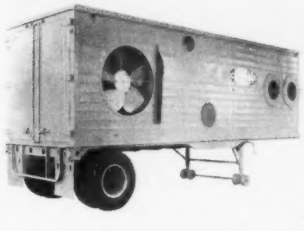


Altitude chamber with external shaker

Concrete test chamber

Packaged "walk-in" altitude test chambers



Mobile test chambers

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Weight of vibration unit:
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Impedance of driving coil:
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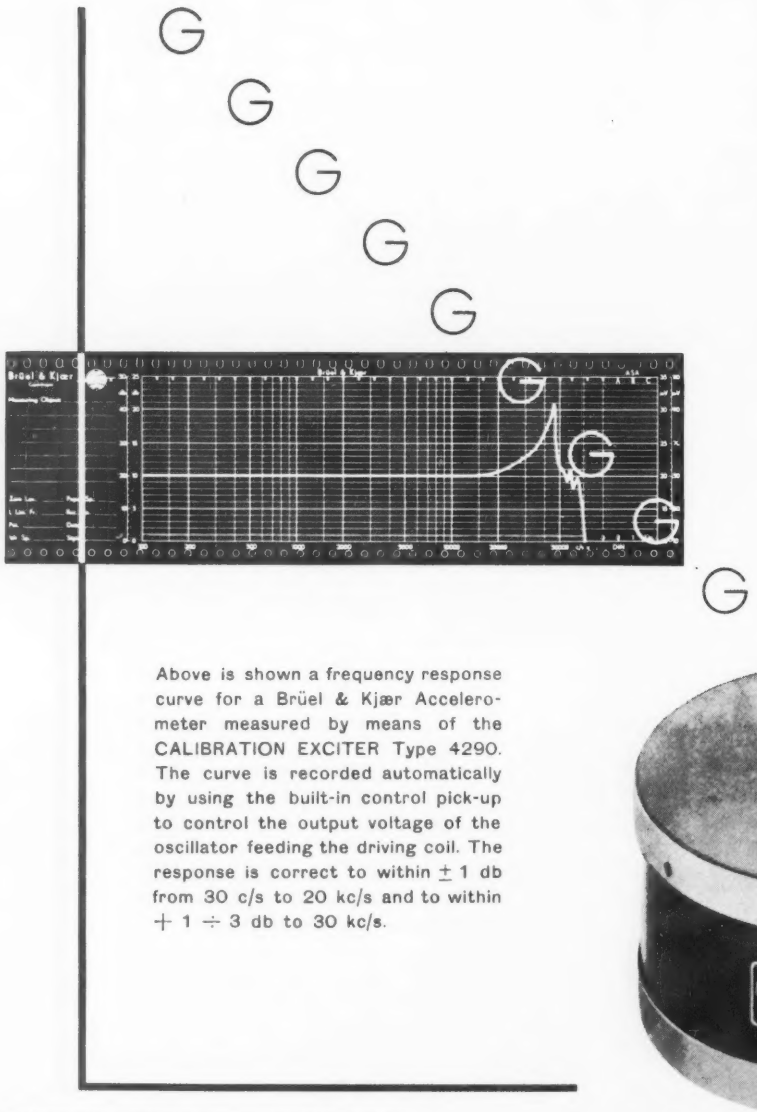

Above is shown a frequency response curve for a Brüel & Kjær Accelerometer measured by means of the CALIBRATION EXCITER Type 4290. The curve is recorded automatically by using the built-in control pick-up to control the output voltage of the oscillator feeding the driving coil. The response is correct to within ± 1 db from 30 c/s to 20 kc/s and to within + 1 ÷ 3 db to 30 kc/s.

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acceleration requirement of the design precepts were envisioned. A yoke device (Figure 3) was designed and fabricated to strap the shakers together at c.g. locations, both to avoid imposing moment loads upon the beam incidental to the imposition of sustained acceleration and also to assure simplicity of the dynamic system. A means of prestressing the accelerator beam in bending was also incorporated in the design of this strap for better control of load paths.

A final modification consisted of the redesign of vibration exciter cradles to provide a means of more positive locking in a given orientation, and also to lower the c.g. as much as possible, again for minimization of centrifugal load in the beam.

A problem of major concern caused by the imposition of vibration and steady–state acceleration in the same axis was the provision of a means for keeping the shaker armature centered in its magnetic field. Conventional flexures are designed for performing this function under normal gravitational loading only. The flexures for the intended application were required to have a range of stiffness some fifteen times greater than that required for normal operation and to be adjustable over the entire range of vibration and acceleration as well. It was decided that pneumatic springs offered the best means of providing the desired range of adjustability. Actuators suitable for this application were adapted in accordance with the design procedure of Appendix 1.

A modification arising from the choice of actuators was the removal of the vibrator degaussing coils to provide space for mounting of the pneumatic cylinders. Figure 3 shows the exciters mounted for coaxial vibration and the actuators in use.

FACILITY SHAKEDOWN:

After all major design and modification problems were resolved, a series of tests was planned to prove design. Figure 2 shows the assembled facility ready for the first shakedown test. With the vibration exciters oriented as shown, with the combined system instrumented with strain gages as described in Appendix 3, and without operating the shakers, the accelerator was rotated and readings of load data were taken in single g increments. As will be seen in Figure 9, the prestress beam load is neutralized by centrifugal action in accordance with the requirement set forth in the preliminary analysis. The stress recorded in the straps was well below design limits.

The procedure described above was repeated with the shakers oriented for coaxial vibration as shown in Figure 3. Loads were considerably greater for this case since the radius of gyration as measured to the shaker armature decreased while the distance to the c.g. of the exciter remained constant. However, total loads were still within the safe operating limits of the tie rods.

The facility was now considered ready for dynamic study under conditions of the simultaneous application of vibration and linear acceleration. For this purpose, the beam, tie rods and specimen jigs were instrumented with accelerometers to permit detection of resonant

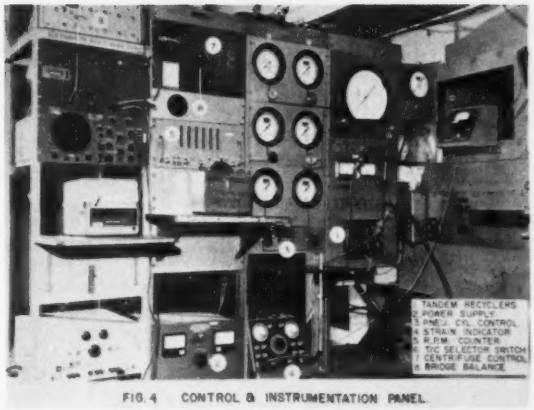


FIG. 4 CONTROL & INSTRUMENTATION PANEL

FIG. 5 VIBRATION POWER SUPPLY & CONTROL CONSOLE

response, and the system was set in operation. Initial data were extremely noisy due to ground loop and line bundling problems.

One source of noise was identified as a voltage induced by the magnetic field of the shaker as it passed the instrumentation terminal strip. Figure 6 is a schematic presentation of the configuration which produced this problem. It also shows how the difficulty was corrected by rerouting the coil hot wire to induce opposing voltages in two legs of the looped instrumentation line. Instrumentation signals were further improved by providing maximum separation between power leads and instrument leads.

Vibration data taken in the course of facility shakedown showed dynamic response throughout the range of operational frequency. Violent response was noted at several frequencies below 25 cps, but in general the response above this frequency was easily controlled by the test operator. A check of system simplicity against the Appendix 2 analysis showed good agreement.

Checkout of the pneumatic spring flexures on the vibration exciters was successful with minor modifications. Some misalignment between the armature and spring axes caused binding of piston rods initially, but the installation of self–aligning rod–end bearings corrected this difficulty. The only other problem was due to

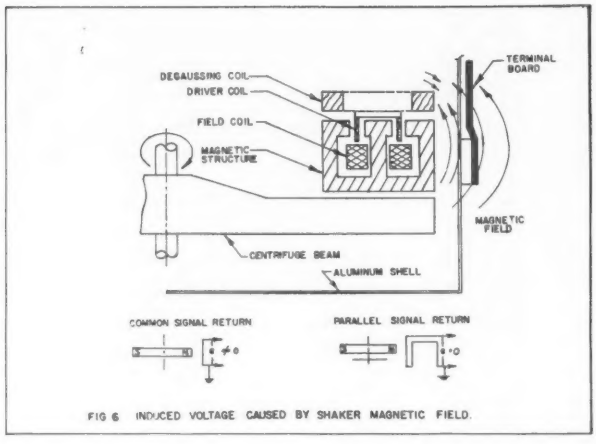


FIG 6 INDUCED VOLTAGE CAUSED BY SHAKER MAGNETIC FIELD.

excessive friction of piston O–rings. This situation was easily corrected by removing two of three O–rings on the piston. Success in the use of these pneumatic springs for centering the armature in its magnetic field at all sustained accelerative loads to 15 g's confirmed the design procedure of Appendix 1.

Provisions for remote control (Figures 4 and 5) proved to be highly satisfactory. Control of accelerator load to within a tenth of one gravity permitted good load regulation, and vibration sensed at the shaker armature could be controlled with the same accuracy either with or without the influence of sustained acceleration. This is to say, insofar as vibration control was concerned, that operation of the accelerator had no deleterious effect.

COMMENTS AND CONCLUSIONS:

The equipment just described has demonstrated its importance to qualification testing throughout the past year. Its operational versatility in the combination of environments has been shown to be a material contribution to the continuing effort toward more faithful reproduction of tactical environments in the Laboratory. Its size lends itself well to the testing of many components and small assemblies and, although it has not to date been used as a portable unit, its convertibility, in accordance with the design precepts, makes possible this highly desirable use. The convertibility feature also permits other than combined testing use of all elements of equipment integrated into this test unit. Facility rentals required to be absorbed by test costs are therefore less. Combined testing is very expensive at best, but it is apparent that the use of convertible equipment results in minimum combined test equipment rental and lower test cost.

Size limitations are found to contribute both favorably and unfavorably to use of the facility. A costwise advantage is realized, of course, from the minimization of specimen size range, since the use of a small facility for testing small specimens is economical. This becomes a serious disdavantage in any case where specimen size exceeds facility capability. Needs in this regard, pertinent to a given application, are worthy of careful study.

The facility which resulted from the effort described, has been found to be close to optimum design, in terms of the above considerations. Although several tests have been rejected upon the basis of facility size limitation, the equipment has been almost completely occupied since its completion and is scheduled heavily for future work.

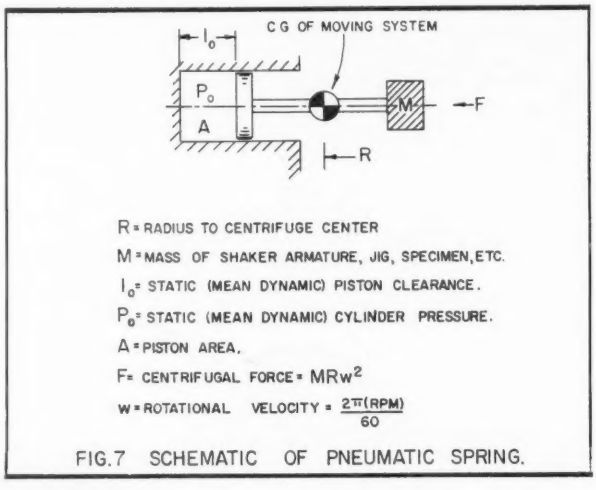


FIG.7 SCHEMATIC OF PNEUMATIC SPRING.

APPENDIX I
DESIGN OF A PNEUMATIC SPRING

In terms of the geometry shown in Figure 7, and assuming a polytropic dynamic process,

PV^n = constant

P = instantaneous pressure

V = instantaneous volume

n = polytropic process coefficient

Differentiating,

$$P n V^{n-1}\, dV + V^n\, dP = 0$$

$$P n dV + V\, dP = 0$$

$$\frac{dP}{dV} = -\frac{Pn}{V}$$

The spring constant of the pneumatic spring is

$$k = \frac{\Delta F}{\Delta l_o} = \frac{A \Delta P}{\Delta V / A} = \frac{\Delta P}{\Delta V} A^2 = -\frac{Pn}{V} A^2$$

$$= \frac{Pn}{A} A^2 = -\frac{Pn A}{}$$

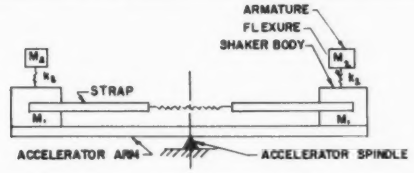
and referencing to mean pressure and clearance,

$$k = \frac{P_o n A}{o}$$

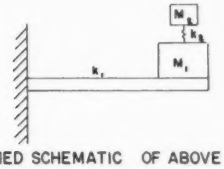
For the range of audio frequencies, an adiabatic process may be assumed. This assumption also applies, without serious error, in the range of frequencies to 5 cps. employing a value of n = 1.4, an expression useful for design purposes, from the above derivation, is as follows:

$$\frac{k}{m} = 1.4 \frac{P_o A}{M_o} = \frac{1.4}{o} \cdot \frac{4\pi^2}{3600} \cdot R(RPM)^2$$

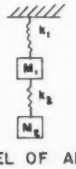
The spring may be designed in terms of limiting dimensions, available actuators which may be employed as cylinders, etc. The procedure is to select values of non–critical parameters which are compatible, in terms of the above expression, with those which are fixed or sharply restricted in range. Simple system natural frequency, proportional to the square root of this quantity, should be kept below ten cycles per second for this application if possible.



A. SCHEMATIC OF ACCELERATOR/SHAKER SYSTEM.



B. SIMPLIFIED SCHEMATIC OF ABOVE SYSTEM.



C. ANALYTICAL MODEL OF ABOVE SYSTEM.

FIG. 8 GEOMETRY AND ANALYTICAL MODEL OF THE ACCELERATOR/SHAKER SYSTEM.

APPENDIX 2
ACCELERATOR/SHAKER SYSTEM RESPONSE FREQUENCIES

Figure 8a shows the principal features of the accelerator/shaker system for shaker orientation in the axis normal to that of the accelerator arm. A similar schematic applies for shaker orientation in the axis parallel to that of the accelerator arm. Figure 8b shows a simplification considered to be valid in consideration of the system and anticipated forcing function symmetry. Note that this simplification combines strap stiffness and that of the beam into one spring constant. This is done since it is not expected that its value will need be obtained; the analysis being in terms of significant frequencies.

Figure 8c shows the equivalent two degree of freedom system employed as an analytical model. This analysis produced a determinant as follows:

$$\begin{Vmatrix} \omega_1^2 - \omega_n^2 & \omega_{12}^2 \\ \omega_{12}^2 & \omega_2^2 - \omega_n^2 \end{Vmatrix} = 0$$

where

$$k_{12} = \frac{k_1 k_2}{k_1 + k_2}, \quad \omega_1^2 = \frac{k_1}{m_1}, \quad \omega_2^2 = \frac{k_{12}}{m_2}, \quad \omega_{12}^4 = \frac{k_2^2}{m_1 m_2}$$

This determinant may be expanded to the form of a quadratic as follows:

$$\omega_n^2 = \tfrac{1}{2}(\omega_2^2 + \omega_1^2) \pm \sqrt{\tfrac{1}{4}(\omega_2^2 - \omega_1^2) + \omega_{12}^4}$$

In this form it is convenient to insert observed frequencies for identification and verification of design assumptions embracing system simplicity, constituent stiffness, etc.

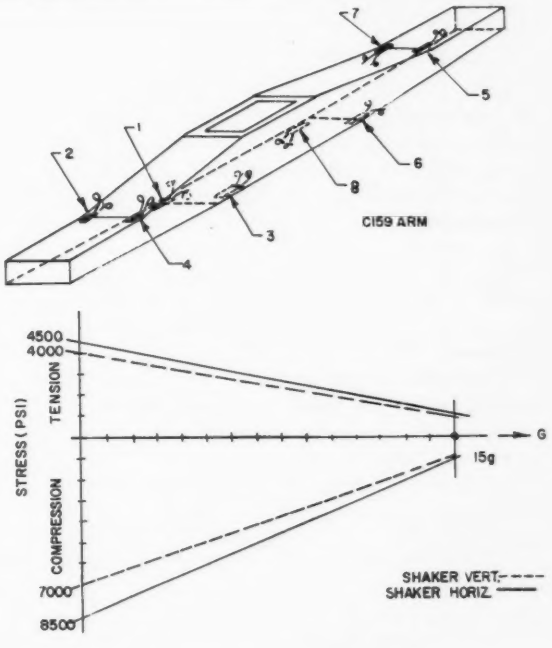


FIG. 9 STRAIN GAGE LOCATION & STRESS CURVES.

APPENDIX 3
DETERMINATION OF MINIMUM PRELOAD FOR CENTRIFUGE BEAM

As noted in the body of this article, a yoke device was designed to counteract the severe loading of the centrifuge beam which would result if the forces acting on the vibration exciters under sustained acceleration were reacted by the beam only. In order to determine the minimum preload in the yoke system which allowed safe operation of the system at 15 g sustained acceleration, strain gages and load transducers were installed on the centrifuge beam and load straps of the yoke device so that preload and bending stress in the beam was read as the centrifuge rotated.

The strain gage type load transducers installed on the load straps of the yoke were calibrated by loading in a universal testing machine and recording strain readings versus load throughout the usable range of the straps. The beam stress was measured by installing eight type A–7 strain gages at critical locations on the beam structure as shown in Figure 9.

Continued on page 29

BIOLOGICAL EFFECTS OF HIGH INTENSITY NOISE

Presented by: WILLIAM P. BAGLEY, B. Aero. E, M.Sc.
Human Factors Group
North American Aviation, Inc.
Columbus Division

ABSTRACT

This article deals with the physiological stresses, both auditory and non–auditory, imposed upon the human being subjected to a temporary environment of high intensity sound. It is especially concerned with effects of intense noise of the type produced by modern jet aircraft.

Information on permanent and temporary hearing losses caused by exposure to high intensity noise is presented. Ear protective devices, their limitations, and human tolerances to noise are discussed.

INTRODUCTION

During the era of propeller driven aircraft, engine and propeller noise experienced by flying personnel and ground crews was considered to be annoying, or at worst, the cause of temporary hearing loss. As a result of this indifference some individuals suffered severe hearing impairment.

With the development of more powerful and increasingly noisy jet engines, the problem of reducing undesirable effects of high intensity noise has become more and more difficult. Noise levels around the aircraft and even in the cockpit have reached proportions which can readily reduce the effectiveness of manned weapons systems unless steps are taken to provide better protection for associated personnel.

The design of protective devices has lagged. The ear protection provided today is limited by the high sound pressure levels produced by jet aircraft. As future engines become more powerful, and hence noisier, the physiological problems connected with noise will increase.

DISSCUSSION

Turbojet and pulse jet engines introduced a new type of illness. German pilots and ground crew personnel attributed loss of appetite, internal bleeding, vomiting, headaches, and discomforts of every description to the high sound levels of these engines. Pilots reportedly lost conscious and crashed. The illness soon crossed the English Channel and lurid stories such as these appeared: A young woman was supposed to have gone into a fit–like state upon placing her tongue in a so called "beam of supersonic sound emanating from a telephone receiver". Curious pains appearing in the bodies of various persons were attributed to the noise of jet aircraft being run upon the ground, even though the aircraft were miles away. News of these strange stories soon filtered throughout the world. Claims were made that "supersonic waves" were causing these peculiar illnesses, so "supersonic sickness" was born. Without a doubt some of the tales had been woven by a vivid imagination. Yet, others seemed to be based on facts. Today, nearly twenty years after the first flight of a turbojet powered aircraft, it is established that sound of high intensity has definite disturbing effects on the physiology of the human being.

The human body has become adapted to and can tolerate noise intensities in a certain range (Fig. 1). Profound silence, as encountered in a completely sound proofed room or the noiseless expanse of a desert produces a feeling of loneliness, often depression and visual illusion. High intensity noise is painful and may cause damage to the hearing apparatus.

White noise is usually defined as being a mixture of sound of all frequencies. Naturally, the human ear is responsive only to a certain range of frequencies contained in white noise and is further limited by the intensity level of the various frequencies (Fig. 2). The point at which the sense of feeling is stimulated is termed the threshold of feeling and is uncomfortably close to the sound intensity which will cause pain in the ears. The lower limit is called the threshold of hearing, below which no sound is heard.

High intensity noise has, in general, two classes of effects on the human body. Those concerning hearing (auditory) and those related to other portions of the body (extra–auditory). First let us discuss auditory effects.

The ear consists of three primary divisions, the outer ear, the middle ear, and the inner ear (Fig. 3). The outer ear is composed of the pinna, or external part, the auditory canal, and the ear drum. The purpose of the outer ear is to channel sound waves to the middle ear.

The middle ear includes a chain of three small bones called ossicles. These ossicles are the hammer, anvil and stirrup. They are so connected that a mechanical advantage of about 30 to 1 is indicated. Their function is to transmit vibrations from the eardrum to the oval window of the inner ear. The oval window is a membrane between the inner and middle ear to which is attached the footplate of the anvil.

The important part of the inner ear as far as hearing is concerned is the cochlea, a spiral tube that resembles a snail shell (Fig. 4). Two membranes divide the cochlea into three parallel canals filled with fluid. The organ of

Corti consists of one of these membranes (the basilar membrane), upon which the hair cells rest and the tectorial or roof membrane.

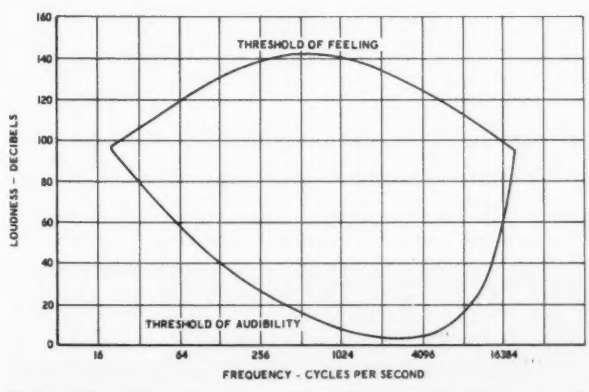
Now, how do we hear? Airborne sound waves enter the auditory canal and are conducted to the eardrum which is activated by the pressure differences. In turn, the ossicles transmit the pressures, greatly magnified by the 30 to 1 mechanical advantage, to the membrane of the oval window. The motion of the oval window sets into vibration the fluid of the inner ear at a frequency corresponding to that of the original sound wave. These pulsations in the cochlear fluid induce resonant vibrations in sections of the basilar membrane which is constructed of increasing lengths of transverse fibers somewhat like a harp. The vibrating sections of the basilar membrane then activate the hair cells which transmit signals to the brain to be interpreted as sound.

FIGURE 1

DECIBELS	TYPE OF NOISE
160	PRESENT DAY JET ENGINES
140	AIR RAID SIREN AT 20 FEET
120	SHOTGUN BLAST
100	PASSING TRAIN
80	AIRPLANE NOISE (SOUND-PROOFED CABIN)
60	OFFICE WITH TYPEWRITERS
40	AVERAGE LIVING ROOM (WITHOUT CHILDREN)
20	WHISPER AT 5 FEET
0	ABSOLUTE STILLNESS

FIGURE 2

NORMAL LIMITS OF HEARING



In general, there are two types of deafness: Conduction deafness, an abnormal condition of the outer or middle ear which prohibits the conduction of sound energy to the oval window of the inner ear. Conduction deafness is always partial since sound energy can be transmitted to the inner ear by bone conduction. The second type is nerve deafness caused by destruction of, or reduction in, sensitivity of the hair cells or nerves of the inner ear. Hearing loss is more pronounced in the higher frequency ranges, but may also involve other frequencies in nerve deafness. Long exposures to high sound pressure levels or old age are typical causes of this type of hearing deficiency which may be either partial or complete, but can never be regained.

One insidious aspect of long exposure to even moderately high noise is that the resulting deafness increases at such a gradual rate as to be not always noticeable to the person until the hearing loss becomes chronic. For this reason audiograms are taken of individuals constantly exposed to high noise levels. Audiograms are plots of the intensity of pure tone frequencies barely perceived by the individual. Figure 5 shows a typical hearing loss caused by exposure to aviation type noises. As a point of interest, women usually indicate a hearing loss in the lower frequencies and men in the higher frequencies.

The first indication of injury to the inner ear is a loss of hearing at 4096 cps with no loss at other frequencies. With a 50 to 60 db* loss at this frequency, difficulty in hearing words like "sister" and "solicitor" is experienced. Repeated and continuous exposure to high level noise may involve frequencies of 2048 cps or 1024 cps, which constitute a definite impairment of hearing. Many cases of permanent deficiency of hearing are accompanied by a constant high pitched tinnitus and sound distortion.

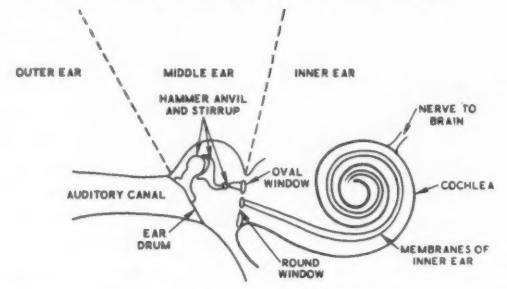
Some pilots suffer a marked degree of permanent loss. The most constant permanent aviation deafness pattern is an abrupt dip at 4096 cps. Twenty-four percent of a group which was examined were affected to the extent that they may experience difficulty in their occupation (1). Engine test stand employees subjected to high sound pressure levels for years from engines run day after day showed a much more marked hearing loss.

There are several theories to account for the initial hearing loss localizing at 4096 cps. The blood supply to the cochlea in this range may be less than normal. The ear may be naturally resonant at 4096 cps and so intensify this frequency. Last, there are indications that a natural hearing depression exists at this frequency and the cochlea may be more susceptible to injury from loud noise at this point.

Like other organs of the body. the hearing mechanism is subject to fatigue, and exposure to moderately high noise intensities may cause a temporary hearing loss. The extent of this loss is increased rapidly during the first period of exposure and then more slowly as the

*Re .0002 dynes per cm^2

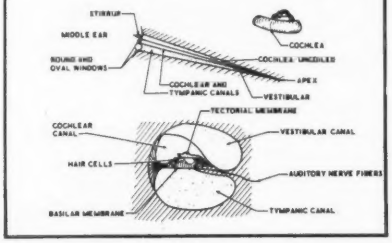
FIGURE 3
SCHEMATIC DRAWING OF EAR



time of exposure is lengthened. Frequency as well as exposure time also has an effect on hearing loss. Noise in the higher frequency range is more effective in producing hearing loss. Upon removal from the noise zone the rate of recovery is rapid for short periods of exposure and slower for lengthy exposure periods. Recovery is normally complete unless the trauma has been too extensive.

Exposure of the average person to 90 db for six to eight hours may cause a hearing loss which returns to normal in an hour or so. A few hours exposure to 115 db can cause a temporary loss in the range of frequency from 2000 to 5000 cps which may return to normal after several hours (1). Exposure to sound pressure levels of 140 db for two minutes caused a marked hearing loss which was still considerable after two hours, but recovery was complete in 24 hours. In some cases there have been no permanent effects after 15 to 20 exposures to sound pressure levels of 130 to 140 db at intervals of several days provided there was nearly complete recovery after each exposure (8).

DIAGRAM OF INNER EAR FIGURE 4



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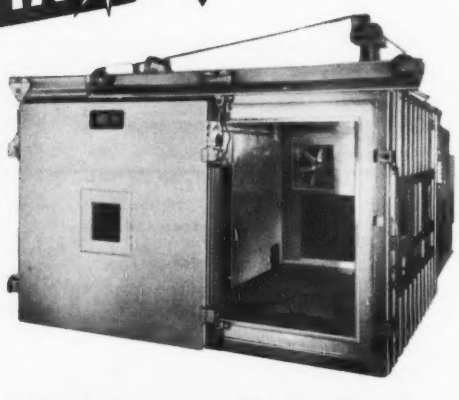

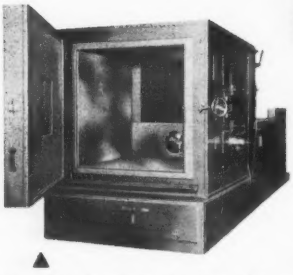

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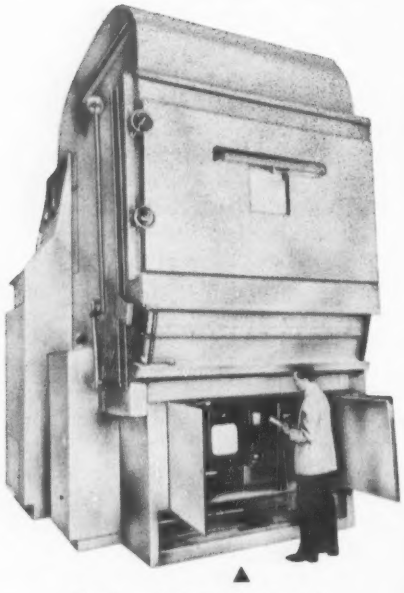

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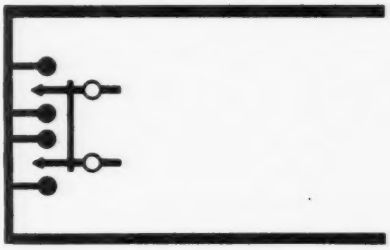

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Critical Environments Encountered by High Altitude Vehicles by B. V. Wacholder and E. Fayer; A study of environmental effects of vehicles and equipment operating on the fringes of the earth's atmosphere and beyond to the moon's surface. Includes a study of the environment before and after vehicle passage and interaction effects between the vehicle and environment.

Effects of Extreme Altitudes and the Need for Simulation by J. C. Simons, Jr.; A discussion of the phenomena expected to be encountered by operation at 150,000 feet. Typical slow rates of vacuum sensitivity will become important only for long flight durations. The closeness with which the low densities of outer space need be simulated is estimated.

The New *"ARDC Model Atmosphere"* Geophysics Research Directorate, Air Force Cambridge Research Center, Bedford, Mass.

Life Sciences and Hyper-Environments by A. M. Mayo; Requirements are described for the control of radiation, temperature, acceleration, noise, vibration, material penetration, internal atmosphere, ecological problems, displays and controls. Ways of implementing these requirements are suggested.

Plant Growth in Outer Space by S. P. Johnson; For long-duration space flights, it has been suggested that green plants be utilized for oxygen production and food. As related to plant growth, the following parameters are discussed: (1) light-dark cycle, (2) temperature, (3) humidity, (4) illumination, (5) weightlessness, (6) high oxygen partial pressure, (7) air movement, and (8) radiation shielding.

Confined Space Feeding by A. C. Avery; Confined space feeding as exemplified by submarine and airplane operations presents food, equipment, and storage problems closely akin to those being faced by space travel scientists. Ration-dense foods, space-saving packaging, compact semi-automatic food preparation equipment, and specially engineered feeding techniques are being researched.

Fixture Resonance Effects on Shock Response by W. J. Reich; Information in the form of non-dimensionalized curves and time histories is presented on the effects of resonances on the response of the system under test.

Considerations of Vibration Environments in Space Flight Systems by George W. Brooks and Sherman A. Clevenson; Discussion of some of the important aspects of vibration during launch and flight phase of space flight systems. Consideration is given to design concepts which minimize the transmission of vibration within the structure. Necessary criteria for simulation of separate and combined vibration environments are presented.

A Proposed Qualification Test Procedure for System Compatibility During Vibration by J. F. Kelleher; The proposed test procedure is intended to provide a method to reduce the cost and time span of component development. This is accomplished by requiring less severe qualification envelopes and to improve the over-all compatibility in a vibration environment.

Continued from page 14

The Journal can publish the results of your studies and research to an extensive circulation throughout the United States and foreign countries as these results are made known during the year. To assist the local chapters in publishing of technical articles, *Russell Lowe*, Vice President of Publications, and I are encouraging appointment of one board member in each chapter to coordinate and select articles written by members in each chapter for publication in the Journal. Please direct your inquiries or articles to *Charles W. Danielson*, 11916 West Washington Blvd. Los Angeles 66, California.

I.E.S. NEWS LETTER

The election of National officers of the IES was announced at the 1960 national meeting in Los Angeles.

The ballots were opened and counted by a committee of tellers consisting of the following IES members; Mr. Donald A. Brosseau, Mr. John H. Boyle, and Mr. Herbert J. Saunders.

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Membership in IES

Several classes of membership are provided in the Institute of Environmental Sciences which parallel those of other societies, namely: Fellow, Honorary Fellow, Member, Associate Member, Student, Government Member, and Company Member. Requirements for the individual classes of membership have been established and will be available upon application for membership. All past members of SEE and IEE have automatically been assigned the member classification without further qualification. Fellows and Members are eligible to vote and hold office. Associate Members may vote but cannot hold office. Student, Government and Honorary Members do not vote or hold office.

APPLICATIONS

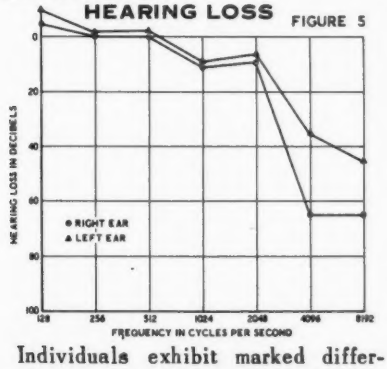
For further information regarding membership write to The Institute of Environmental Sciences, Box 191, Mt. Prospect, Illinois. Attention: Leon Carver, Vice President, Membership.

Continued from page 23

During the tests to determine the minimum preload requirements, all strain gage and load instrumentation was set to zero readings with the yoke device unloaded and the centrifuge not rotating. Prior to starting the centrifuge, the yoke was tightened to approximately 2000 pounds load, and all instrumentation readings were recorded. The centrifuge was then rotated at various speeds between zero and that which produced 15g, and all instrumentation readings were recorded at each speed. At the conclusion of the test, the beam stress versus acceleration curves were plotted and examined to verify the loading characteristics. A typical stress–acceleration curve is shown in Figure 9.

It can be seen from the curve in Fig. 9, that the beam is deflected upwards by the preload and, as the centrifugal load is increased, the stress in the beam approaches a balanced condition at approximately 15g. With this preload, the beam is therefore subjected to a minimum bending stress at the actual operating speed. This condition of operation agrees with requirements of the design precepts.

Continued from page 26



Individuals exhibit marked differences in susceptibility to hearing loss and speed of recovery. For instance, 30% of a group of B–24 and B–17 pilots had a loss of 50 db in at least one frequency and others showed a 10 db loss although exposed the same length of time. One report shows no tendency for those with the greatest initial deafness to be unusually sensitive to auditory fatigue. Some cases indicated an improvement in hearing after 70 hours of flying time.

To be continued in the August Issue

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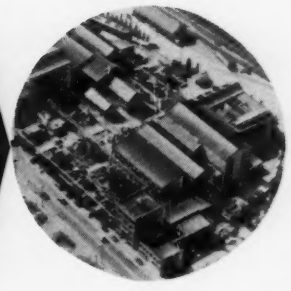

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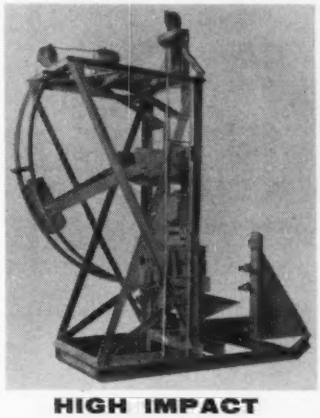

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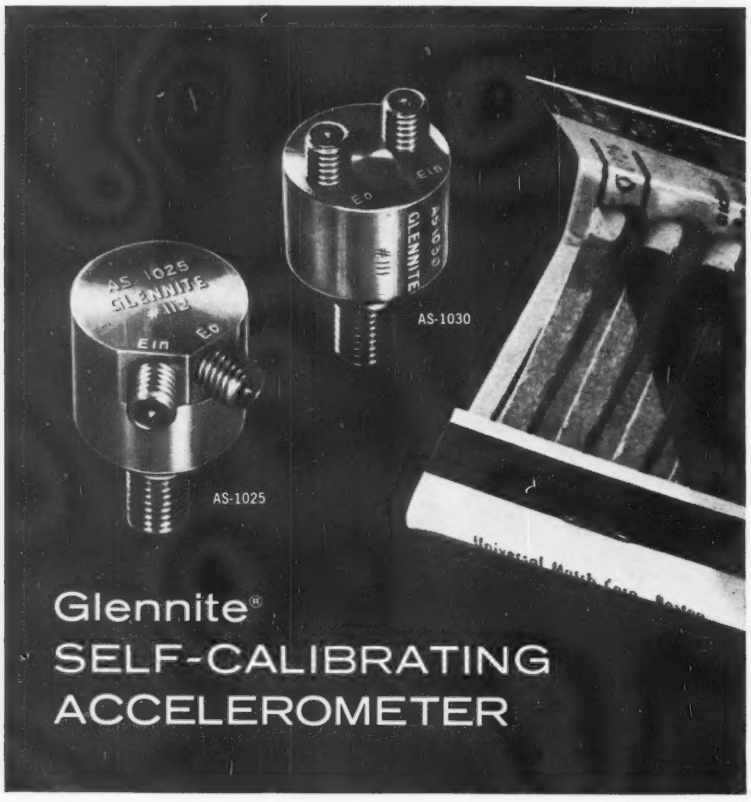


Glennite®
SELF-CALIBRATING
ACCELEROMETER

. . . for pre-flight and in flight calibration

Incorporating a dual seismic system, Gulton's new self-calibrating accelerometer now makes possible increased reliability in data acquisition—not only in the laboratory, but during missile or aircraft flight as well.

The instrument contains two transducers, a sensing element and a driving element. A square wave oscillator, weighing less than five ounces, is available to check accelerometer at pre-flight and in-flight stages. At other times, a small portable oscillator can be used eliminating need for bulky vibrating equipment.

Since both elements can be used as sensors, the accelerometer can be used as a dual output device—thus extending the capabilities of the instrument. For complete details and specifications write:

SPECIFICATIONS

Sensitivity (with 4 ft. cable)	7.5 mv/g (minimum)
Capacitance (with 4 ft. cable)	1000 uuf (minimum)
Resonant Freq.	15 kc (minimum)
Driving Sensitivity	1 volt drive induces a minimum output equivalent to 1.0g acceleration on the seismic system
Weight	AS-1025, side-connected: 21 grams AS-1030, top-connected: 16 grams

GULTON INSTRUMENTATION DIVISION

Gulton Industries, Inc.

Metuchen, New Jersey

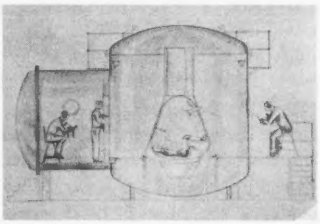
In Canada: Titania Electric Corp. of Canada, Ltd., Gananoque, Ont.

NEW PRODUCTS

TENNEY BUILDING SIMULATOR TO TAKE U.S. ASTRONAUTS INTO SPACE ON THE GROUND

UNION, N.J.--American astronauts will slip into space without leaving the launching pads of Cape Canaveral, Fla., by means of a huge altitude simulator being built here by Tenney Engineering, Inc., major manufacturer of environmental test chambers.

The tank, an extremely high altitude chamber ordered by the National Aeronautics and Space Administration for Cape Canaveral, will accommodate the Project Mercury capsule in which the nation's first space travelers will



be launched into orbit. It will simulate an altitude of 225,000 feet with dive rates so that the astronaut and his space vehicle will function as if they had been hurled into the heavens and were returning to Earth, according to Robert H. Brown, vice president of Tenney.

Mr. Brown said the chamber holding the Mercury capsule will be 12 feet in diameter and 15 feet high. The capsule itself will be lowered into it through a top lid. An adjoining air–lock or anteroom will go up a third of the way or 45,000 feet, and is for observation and safety entrance, Mr. Brown said.

NEW OVEN FACILITATES STRESS TESTING UNDER HEAT

The Electric Hotpack Company, 5009A Cottman St., Philadelphia 35, Pennsylvania, has developed a new oven to permit continual heating of test materials during stress measurement trials. Temperature range: 35°C to 150°C, ±0.5°C. A wheel–and–track assembly allows unit to roll in and out of stress tester with ease, and ceiling and floor openings permit insertion of stress tester jaw

clamps. Controls include wattage selector switch and automatic thermostat plus over–temperature controller which cuts heater circuits in event temperatures exceed thermostat setting. Remote mounted temperature recorder responds to instant temperature changes...forced air circulation provides uniform heat distribution. Glass door permits view of chamber without disturbing internal environment. Enameled steel cabinet, stainless steel chamber.

GULTON UNVEILS SELF–CALIBRATING ACCELEROMETER

Los Angeles, Calif., April 6, 1960--A self-calibrating accelerometer, permitting calibration both before and during the actual flight of missiles or aircraft, was unveiled here today at the Hotel Biltmore meeting of the Institute of Environmental Engineers by Gulton Industries, Metuchen, New Jersey.

NEW PRODUCTS

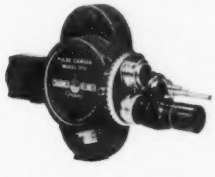
This new concept in "space speedometers" utilizes a dual seismic system, with one element as the driver and the other the sensor, to obtain the novel self–calibrating technique. Both pre–flight or in–flight calibration checks of the accelerometer can be made with a minimum of external equipment by this newest addition to the GLENNITE line of shock and vibration measuring equipment. Once initial laboratory calibration has been made, re–calibration can be effected without the use of elaborate test equipment, an advance which Gulton claims to be unique in the field.

Designated as the AS 1025, the instrument can be used as a laboratory instrument for combined environmental tests such as vibration and temperature, vibration and altitude, and vibration and humidity.

FAST PULSE CAMERA

Chadwick–Helmuth Company, Monrovia, Calif., is in production on an improved Pulse Camera which can be operated at an exceptionally high rate of speed: 30 frames per second. This speed is almost double that of a previous Chadwick–Helmuth model, which was the fastest 16 mm pulse camera available.

Unit uses standard 100' roll film. Versatility has been greatly increased by the addition of a shutter, enabling unit to do all conventional pulse camera work.

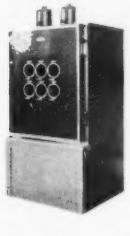


Designated Model 370, this camera is operated shutter–normally–closed for usual pulse photography, and is ideally suited for time–lapse work. Unit quickly changes to shutter–normally–open, for use with SLIP–SYNC slaved stroboscopic light systems.

Auxiliary SLIP–SYNC equipment permits slow–motion movies of cyclic events at speeds of 10,000 cps – an especial advantage in vibration test movies. Slow–motion rate is adjustable, and holds constant for changing speeds. Many scenes can be taken on one roll, and random events or failures are captured.

TEMPERATURE CALIBRATION ENVIRONMENTAL CHAMBER

Point control of ± .1° C. in repeatability, speed of response, and on–off differential plus temperature variation of less than 1° C. within the 6 cu. ft. chamber are provided by this new Harris Environmental Chamber, Model 6L–A2–20. A single–chamber cabinet with temperature range of –20° C. to –85° C., the machine affords



complete recovery in ten minutes with 1000 BTU product load at –65° C.

Further information may be secured by writing Harris Refrigeration Co., 308 River St., Cambridge 39, Mass. The company has specialized in refrigeration service, engineering, and manufacturing since 1934 and has been active in the low temperature field since 1943.

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Use our facilities to evaluate product operation under all environmental conditions. Get automatic alternating cycles of contrasting conditions...remote control of product operation by mechanical, electrical, or hydraulic means...and a wide range of supply voltages and frequencies. Simulate high-low temperatures, humidity, altitude, explosion, immersion, salt spray, sand and dust, rain, fungus, vibration, shock, acceleration, etc. Test to military, government, and commercial specifications.

Complete facilities in the fields of chemistry; metals chemistry; metallurgy; physical testing of materials; engineering analysis of mechanical, electromechanical and electronic devices; site inspection; package testing; psychometrics and certification services for product quality control.

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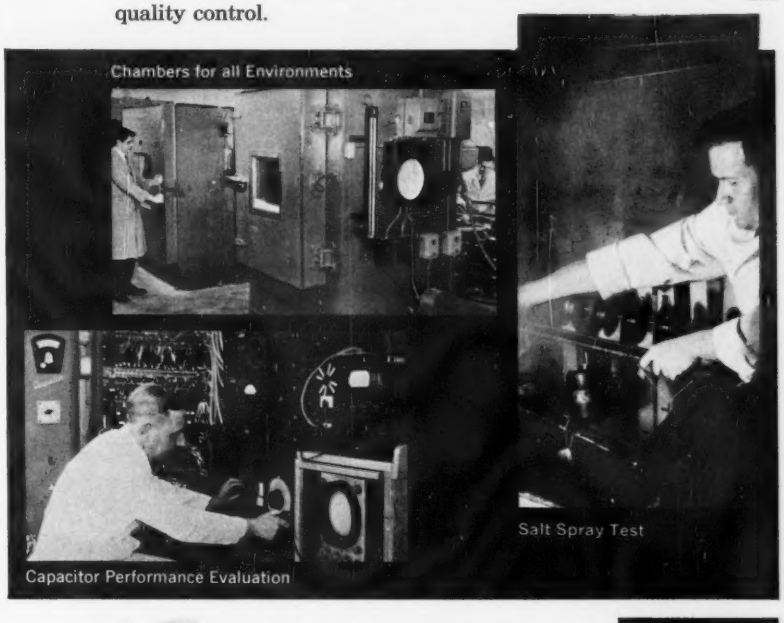

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Strong

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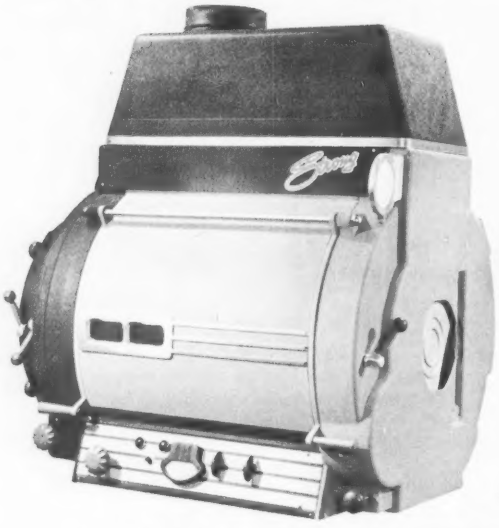
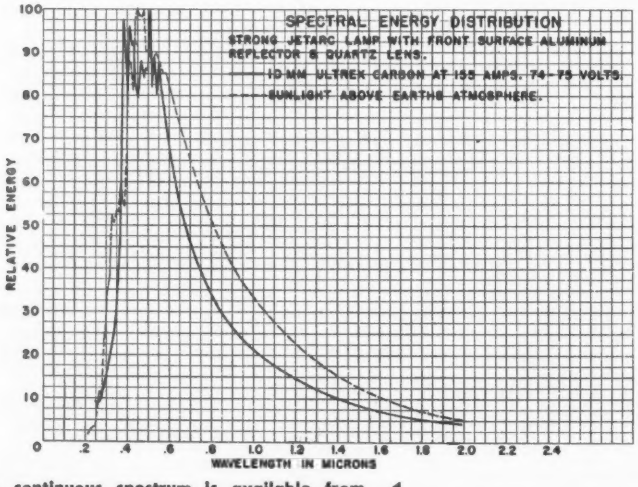


The powerful Strong blown type Jetarc, the most powerful carbon arc, has proved to be the best artificial simulator of solar energy in the development and testing of space vehicle components.

Useful radiation is efficiently collected by first surface reflectors and concentrated at the reimaging point from where it can be projected by a quartz objective system in a pattern shaped to fit the work area. A circular radiation pattern totals 374 watts with an 80% uniformity of field or a total of 668 watts with a 60% uniformity of field. Higher or lower energy unit areas, can be obtained by variation in optics or projection distance. Large areas can be covered by multiple employment of lamps using either superimposed or overlapping pattern technique. Other, less powerful carbon arc sources, are also available for smaller work areas.



A continuous spectrum is available from .25 to 5.+ microns, with the spectral energy distribution very close to solar energy distribution above the earth's atmosphere.

The Jetarc source can be oriented in any plane without loss of stability.

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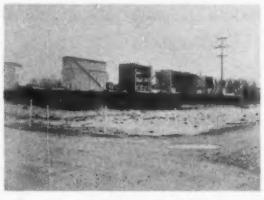
NEW PRODUCTS

WORLD'S LARGEST PREFABRICATED SECTIONAL ENVIRONMENTAL TEST CHAMBER

Conrad, Inc. has just shipped what is believed to be the world's largest prefabricated sectional environmental test chamber. The chamber test space volume is 6,500 cubic feet. Shipment required four railroad cars. This Conrad installation is located with a large West Coast missile manufacturer. Performance parameters included



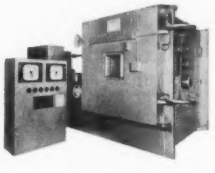
a temperature range of –85°F. to +300°F. and controlled humidity from 20% to 98%. Electronic instrumentation controlled the temperature and humidity program cycles.

A unique feature for the chamber includes a vertically rising full end opening door on the front and back of the chamber. A center partition can be lowered to divide the large chamber into two equal sections. With the chamber divided independent conditions can be controlled in each half.

NEW ENVIRONMENTAL TEST CHAMBER

Extreme range of temperature variations, from –100° F to +1000°F, is now available in this new environmental test chamber just completed by the American Research Corp., Farmington, Conn.

Designed to simulate conditions which might be encountered by outer space vehicles, the chamber produces both high and low temperatures by radiation from all six sides as well as by convection, thus reproducing true,



high altitude conditions completely around the test specimen.

In addition, at any temperature and at any altitude up to 150,000 ft., the gradient throughout the chamber can be held as closely as ±5°F.

The chamber illustrated has a free test space of 4' x 4' x 4' and is equipped with mechanical refrigeration capable of dissipating a heat load at the rate of 7500 watts at –70°F.

LING ANNOUNCES NEW S–14 SERVO SYSTEM

The S–14 Servo System offers control accuracy of less than 3 percent variation in controlled level for system resonances up to 50 db and has a varying response time. The reaction time is less than 5 cycles for 90% correction of 10 db gain reduction, – less than 5 seconds to correct within 10% a 10 db gain expansion at 5 cps decreasing with increasing frequency to 50 milliseconds at 5 kc.

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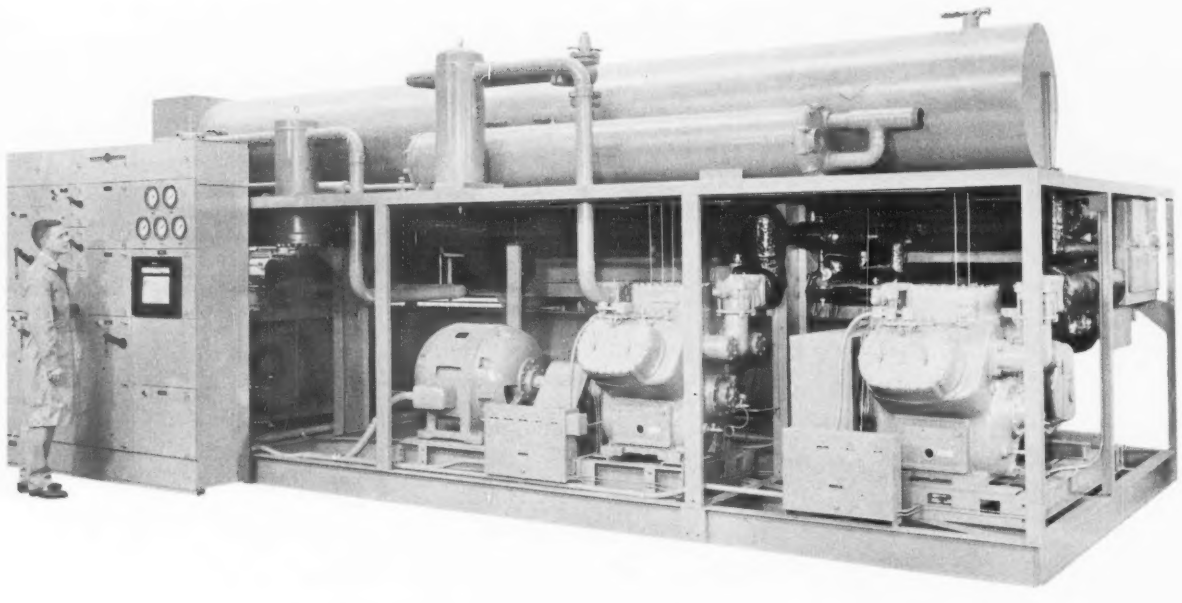
325 HP LIQUID COOLER . . . .

This "packaged" liquid cooling system will produce temperatures in the range of –100° to –125° F, with a coolant flow rate of 600 gpm.



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The Vibration Exciter is the LCM 100 which features a horizontally moving push pull driven table. The shaker table is supported by air bearings which stiffly confine movement of the table in all directions but the axis of excitation. This new air suspension system eliminates troublesome springs and flexures; and reduces crosstalk, a major problem with many shaker systems, to an exceptionally low value.

"Heavy" specimens are easily handled as the weight of the table and specimen is supported by air pressure normal to axis of excitation.

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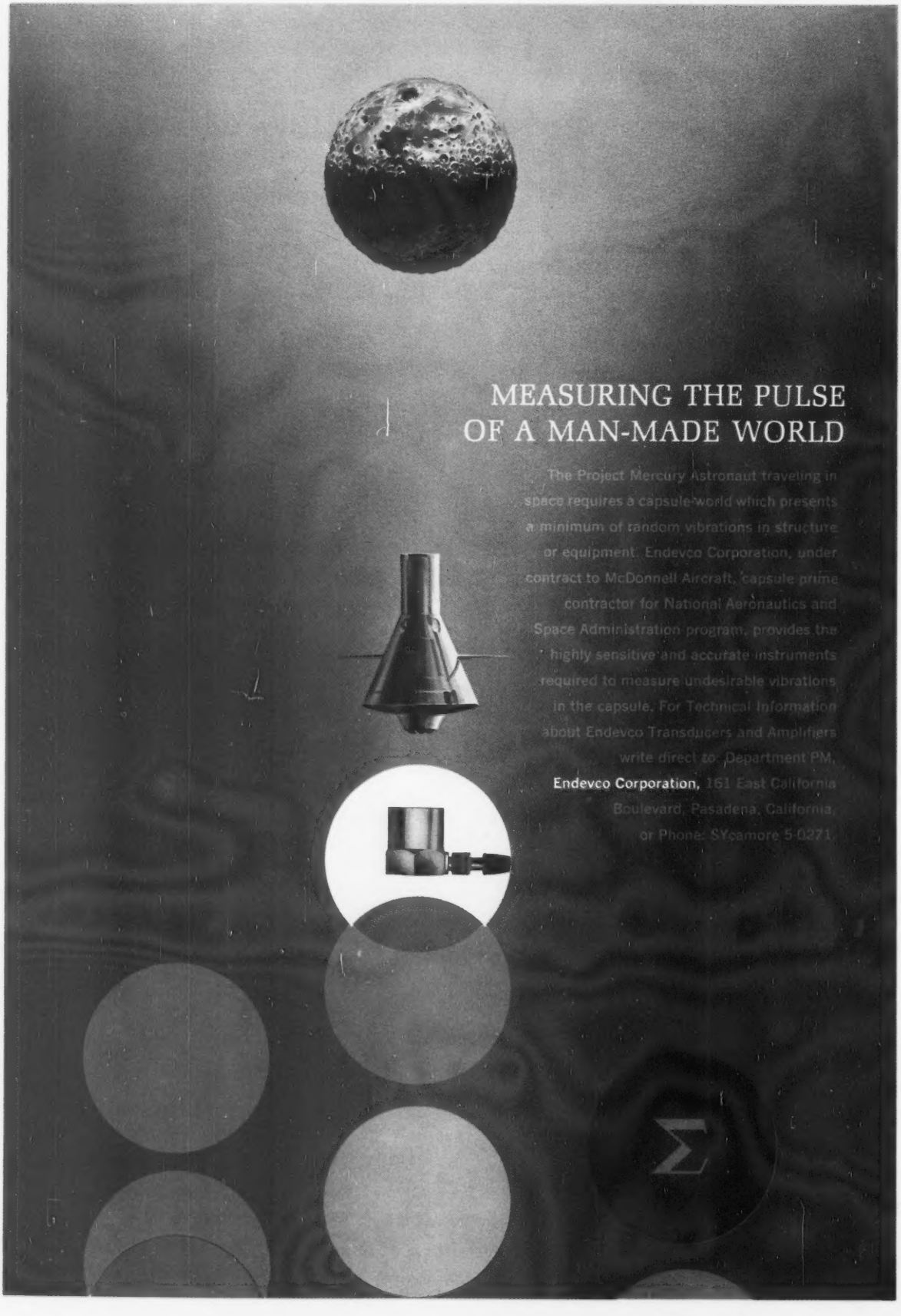
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The Project Mercury Astronaut traveling in space requires a capsule-world which presents a minimum of random vibrations in structure or equipment. Endevco Corporation, under contract to McDonnell Aircraft, capsule prime contractor for National Aeronautics and Space Administration program, provides the highly sensitive and accurate instruments required to measure undesirable vibrations in the capsule. For Technical Information about Endevco Transducers and Amplifiers write direct to: Department PM,
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Genisco Model A903 features simplified operating procedures; rugged construction...for fast, accurate testing to MIL-E-5272A, Procedure II

Although the A903 is a simple, low cost centrifuge, it has many features found in more sophisticated machines, *plus* unique features which particularly suit it for production-line testing and evaluation programs.

SIMPLE OPERATION—Except for an on-off switch, controls are limited to a single handwheel which controls table speed. Chance of human error is reduced to a minimum. Test personnel can learn its operation in minutes.

SPEEDS TESTING—24" diameter mounting-table will accommodate several test objects. Arranged symmetrically, they can be subjected to acceleration forces simultaneously.

RUGGEDLY-BUILT—Virtually immune to operational abuse. Will operate for long periods without maintenance as demanded for production test programs.

0.5% ACCURACY—Constancy of rotation of the mounting-table is within 0.5%, including wow and drift. Table rotation speed can be measured electronically within ±1 count.

BRIEF SPECIFICATIONS

G-Range: 1 to 1,000 g's in five standard ranges, infinitely variable

G-Pound Capacity: 2,500 g pounds, maximum

Constancy of Rotation:

Wow: 0.5%, maximum

Drift: 0.2% of rate per minute, maximum

Speed Indication Accuracy:

Tachometer: ±1¼%

Magnetic Pickoffs: 60 tooth pickoff gear standard; 600 tooth gear optional. Pulses are fed to a front panel coaxial receptacle for use with any standard electronic counter.

Vibration Isolation: 0.1 g in any plane, at any speed

Test Object Dimensions: 8" high (24" diameter circular platform)

Slip Rings: 8 standard, 10 amp. maximum

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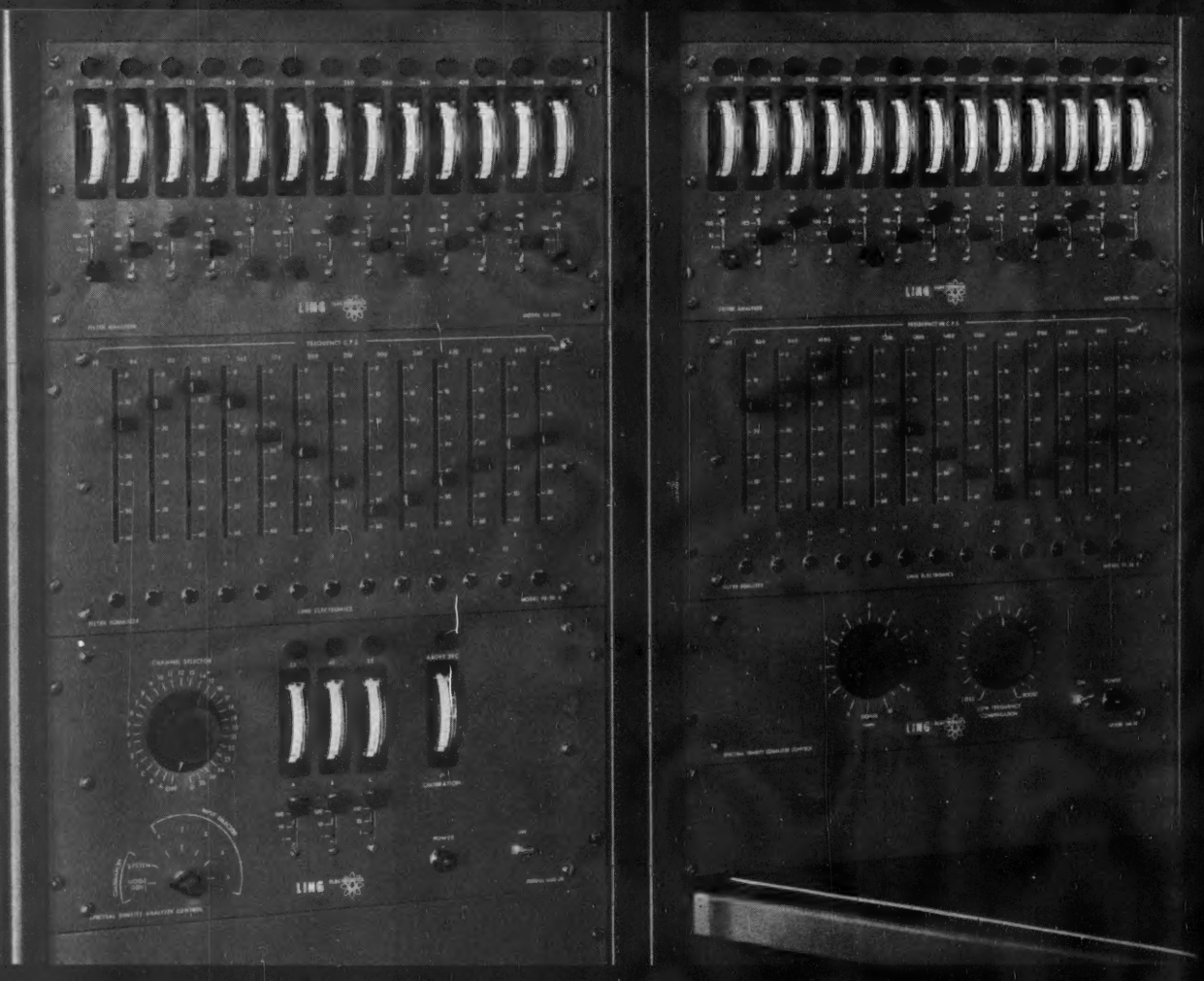
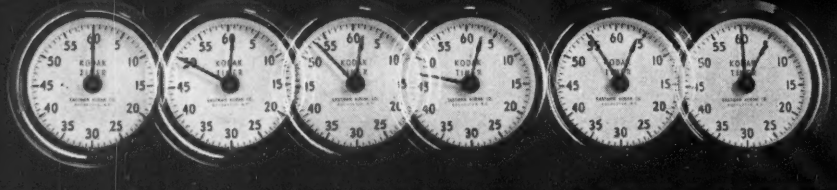
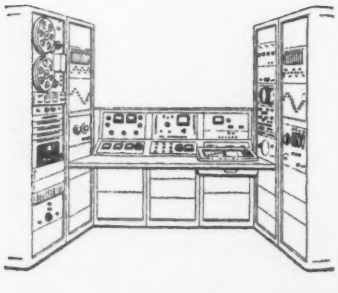




LING BREAKS THE RANDOM TEST TIME-BIND WITH A NEW FAST SET-UP



Now Ling brings you another breakthrough in random noise testing. Ling's new Equalizer-Analyzer system lets you set up a shaped input in minutes, analyze unknown variations at a glance and equalize spectrum shifts even while the test is in progress. The simplified controls of this remarkable system feature a series of separate adjustable attenuators which split the entire bandwidth of 10 to 2000 cps into segments of 100 cps or less, giving the operator independent control over each segment. Band-pass characteristics of the analyzer filters are matched to those of the equalizer, giving the operator a continuous picture of shaker acceleration output, calibrated directly in g^2/cps, segment by segment, for an analysis that is 30 times faster than the usual sequential scanning method. Corrections in energy distributions can be made in minutes simply by adjusting the filter attenuators. Enables fast set up without the tedious wait for slow types of analysis, gives you sure control and a correct-as-you-test system. For details, write for a copy of a recent paper on the subject by J. A. Ross, Vice President, Research and Development. And for electronics that help you get out of prototype into production *fast*, look to the leader—Ling Electronics. Dept. JE–3

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